

# **Single Queue Priority Scheduler for Video Transmission in IEEE 802.11 Networks**

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This thesis is submitted in partial fulfilment of the academic requirements

for the degree of

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As the candidate's supervisor, I have approved this dissertation for submission.

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Date: \_\_\_\_\_

## Declaration

I declare that this thesis is my own work. Where collaboration with other people has taken place, or material generated by other researchers is included, the parties and/or materials are indicated in the acknowledgements or are explicitly stated with references as appropriate.

This work is being submitted for the Master of Science in Electrical Engineering at the University of Cape Town. It has not been submitted to any other university for any other degree or examination.

Signed by candidate
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Joshua Adejare ADELEKE

21-05-2015

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Date

# **Dedication**

To God Almighty.

To my parents Isaac and Victoria Adeleke.

# Abstract

Mobile video transmission poses many challenges in standard wireless network like Wireless Local Area Network or IEEE 802.11. The challenges range from handover, delay, packet loss, jitter, fading and signal loss. Some studies have suggested an increase in network resources as a way to cater for the huge demands and reduce congestion in the network, while others suggest that optimizing the available resources might also reduce these challenges.

In line with the optimization approach, this study proffers a solution to the video loss in IEEE 802.11 networks. It uses the Single-Queue Priority Scheduler to rearrange the video frames based on their importance. An MPEG frame (trace file) was rearranged by assigning weights to the video frames I, B and P. These frames were then prioritized and arranged in a single queue. A parameter to actively arrange the queue ( $Sn$ ) was deduced from three metrics- deadline, priority and cost. This value  $Sn$  was used to arrange the video trace or frames from the lowest to the highest. The arranged video trace or frames were injected into the queue and transmitted in that order.

The results show that the implementation of Single-Queue Priority Scheduler algorithm improves the video transmission in Wireless Local Area Network. Without Single-Queue Priority Scheduler algorithm, the buffer overflow loss is 22.8% of the total load, but with SQPS algorithm, it is 8% of the total load. Without SQPS algorithm, the Packet Loss Ratio is about 61%; but with the SQPS algorithm, the PLR reduces to 34%. Although, this scheduling algorithm produced better results with a reduction in packet loss, there were still some losses in the network.

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# Glossary

**Access method:** This term generally refers to a scheme by which stations may access a network via a shared medium. See also channel access protocol.

**Access point (AP):** Typically, infrastructure-based wireless networks provide access to the wired backbone network via an AP. The AP may act as a repeater, bridge, router, or even as gateway to regenerate, forward, filter, or translate messages. All communication between mobile devices has to take place via the AP.

**ACK:** Generally refers to the acknowledgment of the receipt of the last transmission.

**Ad hoc network:** A class of wireless network architecture in which there is no fixed infrastructure or wireless access points. In ad hoc networks, each mobile station acts as router to communicate with other stations. Such a network can exist on a temporary basis to share some resources among the mobile stations.

**Backbone:** A network of high-speed communication lines that carries the bulk of the traffic between major segments of the networks.

**Backoff:** The retransmission delay (usually random) enforced by contention media access control protocols after a station that wanted to transmit sensed a carrier on the physical medium.

**Bandwidth:** In general, the theoretical capacity (measured in bits per second or slots per second) of a data communication channel.

**Bit rate:** The speed at which bits are transmitted, usually expressed in bits per second (bps). See also bps.

**bps:** Bits per second. Represents the rate at which data can be transmitted across a network. The number of bits per second may differ from the baud rate because more than one bit can be encoded in a single baud.

**Broadband:** A broadband transmission employs several transmission channels on a single physical medium. Thus, more than one node can transmit at a time. In New Zealand, Telecom's Jetstream is an example of a broadband technology.

**Collision:** When two or more packets are simultaneously sent on a common network medium that only can transmit a single packet at a time. The packets collide and are corrupted and need to be re-sent.

**CSMA:** Carrier sense multiple access. This is a channel access method in which a station senses the channel (e.g., listens to the channel) before sending a packet into the network—trying to find out whether another station is attempting to send a signal at the same time.

**CSMA/CA:** Carrier sense multiple access with collision avoidance. This is a popular access method used by wireless LAN. Before transmission, a station senses the channel. If the channel is idle, the packet is transmitted right away. If the channel is busy, the stations keep sensing the channel until it is idle, and then waits a uniformly distributed random backoff period before sensing the channel again.

**Direct sequence spread spectrum (DSSS):** A transmission technique used to avoid interference and achieve a higher throughput. Instead of a single carrier frequency, a sender and receiver agree to use a set of frequencies concurrently. The practical application of DSSS is in wireless LAN.

**Ethernet:** A popular LAN technology that uses a shared channel and the CSMA/CD access method.

**IBSS:** Independent basic service set. A wireless LAN configuration without access points. IBSS is also referred to as ad hoc mode wireless network.

**IEEE:** Institute of Electrical and Electronic Engineers. It is one of the largest professional nonprofit organizations in the world. IEEE defines network standards (e.g., IEEE 802.11).

**Infrastructure network:** A class of wireless network architecture in which mobile stations communicate with each other via access points, which are usually linked to a wired backbone. Such a network has a fixed infrastructure and a centralized control.

**Network traffic:** The network traffic denotes the number, size, and frequency of packets transmitted across a network at a given amount of time.

**Node:** Any device connected to a network such as a personal computer (PC), a mainframe computer, a router, a printer, or other network equipment.

**Packet:** A generic term used to define a unit of data, including routing and other information that is sent through an Internet.

**Packet forwarding:** The process by which protocol data units in a packet-based network are sent from their source to their destination.

**Packet switching:** A transmission method in which packets are transmitted over a networking medium that maintains several paths between the sender and the receiver.



**Physical topology:** This refers to the way computers and other devices are connected on the network physically.

**Protocol:** A protocol is a collection of rules for formatting, ordering, and error-checking data sent across a network.

**Routing:** A process that occurs on a network when a packet is shunted from router to router along the path to the target destination.

**SQPS:** A Single Queue Priority Scheduler designed to prioritise video traffic using deadline, priority and cost metrics in a low bandwidth wireless environment.

**Wireless channel:** Generally refers to a communication medium in which signals travel through space instead of through a physical cable. Electromagnetic radio waves are used as a wireless channel.

**Wireless LAN:** Refers to a LAN that uses infrared or radio frequencies rather than physical cable as the transmission medium.

**Wireless link:** Generally refers to a pathway for the transmission of information via a modulated unconstrained electromagnetic wave.

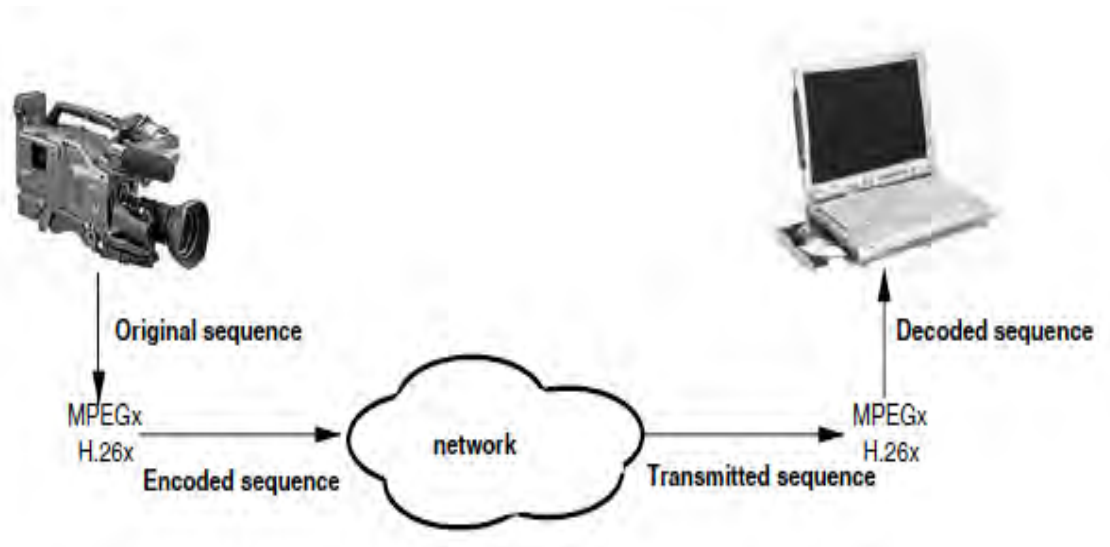
**Workstation:** An end user computer that has its own CPU and is used as a client to access another computer, such as a file server.

# Chapter 1

## 1 Introduction

### 1.1 Video Transmission

Video transmission is the movement of video packets from a source to a destination (see Figure 1.1). The video packets can be either an analogue or digital in nature. The analogue video uses an electrical signal to capture images on a magnetic tape. Examples of analogue video formats are VHS, VHS-C, 8mm, Hi8, Video8, Betamax and SVHS. The digital video signal is a pattern of 1's and 0's that represent the video image. Once the digital video is captured, there is no variation in the original signal, nor does the image lose any of its original sharpness or clarity. A digital video is an exact copy of the original. Examples of digital video formats are AVI, MP4, 3GP, FLV, WMV.



**Figure 1.1: A wireless video transmission system**

## 1.2 The Importance of Video Transmission

Video transmission is important for many aspects of living (e.g. communication, entertainment, education, etc). For instance, it has application in the Internet world or websites. In this modern culture, videos are increasingly used on the internet for selling products, developing video blogs or websites as videos make it easier to explain one's thought in comparison to text. It is also, often times, more pleasant to watch a video than to read text on computer screen. A good example is YouTube or similar sites, that stream video over the internet. Video transmission is also useful for remote monitoring in oil and gas industries for operation awareness (Jain 2011). It plays a crucial role in Netflix news and entertainment, and in on-line learning modules like “Coursera”. Communication has also improved interaction and reduced cost with the emergence of video conferencing. For example, Skype video calls can be made without any cost. Video streaming has applications on smart phone, which provides means of communication, particularly in regions where there is no wired infrastructure or Internet. Video transmission also has applications in medicine. For example, telemedicine (see Figure 1.2) provides opportunities where doctors can remotely communicate with their patients using mobile video wireless links. Here human lives may depend on the continuous streaming of video.



**Figure 1.2: Applications of video transmission in telemedicine**

Owing to its importance, video transmission has experienced a rapid growth in the last decade. For instance, the percentage contribution of video streaming to Internet traffic increased from 13% in 2008 to 27% in 2009 (Jain 2011). It is projected that the video growth rate may account for more 66% of the total Internet traffic by 2017 (Cisco 2014). In the United States of America (U.S.A), 81% of the Internet traffic was streaming video and this grew to 84.4% in October 2009. The average time spent with streaming video has increased in the US from 8.3hours/month to 10.8 hours/month within a time span of three months in 2009. To illustrate growth in income from video streaming, earnings from streaming video alone was expected to increase from \$1.37billion in 2008 to \$4.5billion in 2011 with a 228% increase (Jain 2011).

### **1.3 Video Transmission in Wireless Networks**

Videos transmitted in wireless networks are also known as video streaming. The wireless network used in this study is the infrastructure based wireless local area network (WLAN). The WLAN is known as the IEEE 802.11 network standard or in some cases Wireless Fidelity (WiFi). The IEEE 802.11 defines the Physical layer (PHY) and Media Access Control protocols. WLAN standard uses a Direct Sequence Spread Spectrum (DSSS) as the modulation technique. The MAC protocol defines the Distributed Coordination Function (DCF) as the base access mechanism to control the way nodes access the network and coordinate communication between nodes. The DCF uses the Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) to control access to the channel using the four-way handshake. Before a node transmits a video packet, it senses the channel by sending a Request-To-Send (RTS) while the destination node replies with a Clear-To-Send (CTS) message if the channel is free to avoid collision (Xiao 2003; Salkintzis & Passas 2005). Orthogonal Frequency Division Multiplexing (OFDM) is a

modulation scheme that is incorporated in WLAN. Its Multiple Input Multiple Output (MIMO) technology that allows channels to be further partitioned into subchannels for enhanced network performance particularly in the throughput. Multiple nodes can transmit and receive video traffic with one or more antennas.

## **1.4 Quality of services for Video transmission in Wireless Networks**

Quality of Service (QoS) is the guaranteed level of performance provided by prioritizing different classes of applications, users or data flows. The premise of QoS is that some traffic are more important and should be given priority. Furthermore, the Internet has become mission-critical to many companies. From the viewpoint of a customer (a user, an organization or another provider), the first step towards the QoS is the Service Level Agreement (SLA), which is negotiated with a provider (Kamel et al. 2009). The SLA defines, among other things, the QoS requirements, the anticipated load and the actions to take if the load increases above the negotiated value or pricing. Since the SLA includes rules and actions in a human readable form, it has to be translated into the machine-readable representation. For these purposes, the SLA is partitioned into several documents. The Service Level Objectives (SLO) specifies metrics and operation information to enforce and monitor the SLA. The Service Level Specification (SLS) specifies the handling of a customer's traffic by a service provider (Goel & Member 2008). To characterize the QoS requirements and actions in the SLS, a provider and a customer must specify them with a set of well-known parameters, or performance metrics, so that a provider can translate them into the router configuration. The fundamental parameters are throughput, delay, jitter, and packet loss (Ludovici 2006).

### **1.4.1 Throughput**

Throughput specifies the amount of bytes (or bits) that an application can send during a given time unit without losses. It is one of the most important parameters as most applications include it in the set of their QoS requirements. It is important to note that the throughput represents the long-term rate of an application. Due to the packet-based nature of most networks, the short-term rate may differ from the long-term value. Therefore, the throughput usually refers to the average rate of an application. Consequently, one can use other parameters such as the maximum or the minimum rate.

### **1.4.2 Packet delay**

Packet delay is a fundamental characteristic of a packet-switched network and it represents the time taken or required to deliver a packet from a source to its destination. It is also referred to as an end-to-end delay. Each packet inside a network is routed to its destination via a sequence of intermediate nodes. Therefore, the end-to-end delay is the sum of the delays experienced at each hop on the way to the destination. It is possible to think about such a delay as consisting of two components, i) a fixed delay which includes the transmission delay at a node and a propagation delay on the link to the next node, and, ii) a variable component which includes the processing and queuing delays at the node.

### **1.4.3 Jitter**

Jitter is the end-to-end delay variation between two packets. It is an important parameter for the interactive applications, such as on-line audio and video conversations. Since data exchange between two applications involves sending a significant number of packets, it is often the case that, jitter is the delay variation between two packets. However, one can also use a smoothing equation to obtain some mean value over the sequence of packets. Ideally, regardless of the interpretation, the jitter should be equal to

zero because the bigger its value, the larger the buffer of a receiving application must be to compensate for the delay in variations between the packets.

#### **1.4.4 Packet loss**

This characterizes the number of dropped packets during transmission. This parameter is critical for those applications that perform guaranteed data delivery because every time a router drops a packet, a sending application has to retransmit it which can result in ineffective bandwidth utilization. It is also important for some real-time applications since packet drops reduce the quality of transmitted video and/or audio data. Since the number of dropped packets depends on the duration of a session, the packet loss is usually expressed as a ratio of the number of dropped packets to the overall number of packets (Zodi 2011; Kakande 2010; Setongo 2010).

### **1.5 Quality of experience for Video transmission in Wireless Networks**

The Quality of Experience (QoE) in video transmission is the overall level of customer satisfaction engaging with the video. While the QoS is network-focused and deals with the service provider, the QoE is user-focused and quantifies how the user has enjoyed his video experience. A metric known as the Mean Opinion Score (MOS) is often used to quantify the quality derived from the video content by a user. When automated, the MOS of a video is estimated by feedback on the characteristics of the video and the network streaming it, using an algorithm (Politis et al. 2012). Previously, the MOS was calculated manually by recruiting end-users to watch the videos and give a numeric score after engaging with it. The values of the MOS ranged from 1 to 5, where 5 represents the highest quality and 1 the lowest quality. For example, a video rated with a MOS of 3.96 relative to its counterpart has a MOS of 3.53. It is essential to measure the MOS as a

relative measure of the quality of the video. The automated results are usually preferable because they are more accurate and less expensive (Cerqueira et al. 2010).

## **1.6 Challenges of video transmissions**

There are challenges in video transmission through wireless networks. The challenges are related to the bandwidth, delay and packet loss in video streaming (Wu et al. 2000).

### **1.6.1 Bandwidth**

To get satisfactory video quality, video transmissions have basic bandwidth requirements. Since the Internet does not differentiate between classes of traffic, it does not provide bandwidth reservation for delay sensitive traffic like real-time videos. With extreme traffic on the wireless network, the throughput of the video can be degraded.

### **1.6.2 Delay**

Real-time video are delay sensitive unlike data traffic that do not have delay limitations. The end-to-end delay parameter in a video network gives the time a video must arrive at the destination and be decoded and displayed. A delay in the arrival of a video packet in a streaming network negatively affects the playout of the video stream which is displeasing to the user. The Internet does not give priority to delay sensitive traffic hence, video packets that exceed the time limit is dropped and considered lost. In a congested network, there will be excessive delays that exceed the time constraints of a real-time video.

### **1.6.3 Loss**

Loss of video packets can make its presentation unpresentable or disappointing to the human eyes. Due to this loss, video streaming applications use packet loss



requirements to enforce some prerequisites. A defined packet loss limit that cannot be exceeded is usually setup to get an acceptable video quality. Although real-time multimedia traffic have packet loss limits, the Internet offers a best-effort delivery with no guarantees that the video packets will be delivered. The major causes of packet loss in wireless networks are congestion and buffer overflow.

## **1.7 Wireless Scheduling Mechanisms**

Gabale et al. (2013) classifies scheduling algorithms are classified in based on four distinct sections. These are Goals, Inputs, Problem Settings and Techniques of the scheduling mechanisms.

### **1.7.1 Goals**

This simply refers to what the scheduling mechanism plans to achieve (i.e. goals of the scheduler). The scheduler usually looks for the best schedule that achieves some laid down objectives. These objectives can range from minimizing delay to maximizing the throughput in the system by reducing the packet loss. Additionally, scheduling for real-time traffic can be an objective (Gabale et al. 2013).

### **1.7.2 Input**

This classification considers various parameters such as QoS, number of channels and radios, state of the channel that serve as inputs to solve the scheduling problem (Gabale et al. 2013).

### **1.7.3 Problem Setting**

A channel access type (TDMA/CSMA), antenna type (Omni-directional/Sector), scheduling control (Distributed/Centralized) and network topology type (Tree/Graph) all combine to determine how a scheduling mechanism allocates resources. In our proposed scheduling algorithm, the SQPS is applied in a WLAN that uses the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) channel access type. The network setup in our simulation emulates the star topology with nodes connected to the

wireless access point (Sarkar 2014). This study focuses on the research of low bandwidth video streaming in wireless networks.

#### **1.7.4 Techniques**

A combination of goals and problem settings determine the technique used in the scheduling mechanism. These can involve the use of heuristics, graph properties, linear programming formulations and max-flow based techniques that determine the effectiveness of the algorithm. In the proposed scheduling algorithm, a heuristics technique was used.

### **1.8 Issues in Wireless Scheduling**

The scheduling algorithms are numerous and will be categorized based on their functions and the issues that they address. The link variability is a major difference between wired and wireless networks. Due to this high rate of loss in the transmission media, packet transmission suffers from a high error rate. This loss can be caused by interference or fading in wireless networks.

#### **1.8.1 Fairness**

Unlike wired networks, that are mostly error-free, the wireless network is error-prone. A packet can be corrupted and this can waste transmission resources. In this case, deferring transmission of this packet until the link recovers from the error state is clearly a reasonable choice. The affected flow, hence, temporarily loses its share of the transmission bandwidth. Using Cyclical Scheduling Algorithm (CSA), the authors in Velepini and Dlodlo (2009) correlated network performance to the size of workstations in the wireless system. The simulations from this study established that as the workstations increase from two to fourteen, network performance does not necessarily improve but the data flows increase thereby increasing the scalability of the network. However, the increase in the scalability does not bring down the performance of the wireless network.

### **1.8.2 Link Variability**

Time and location dependence is a key issue in wireless networks regarding the stability of the network. There is high variability as wireless links suffer from fading and interference. This makes them highly error prone and they do not have the benefit of a low error rate like the wired networks. The physical location of a mobile terminal and its proximity to the base station also increases the chances of error-free communication. These link variations require that the scheduling algorithms should be equipped with certain dynamic mechanisms that can deal with these time-dependent and location-dependent changes. The Optimized Network Engineering Tool (OPNET) simulator models the wireless channels as Gaussian. This study assumes the default OPNET setup for the wireless channels.

### **1.8.3 Quality of Service (QoS)**

Wireless networks service different classes of traffic (data, voice and video) with varying requirements. The heterogeneity of these traffic flows require QoS guarantee and differentiation. The Type of Service (ToS) employed usually determines the prioritized scheduling.

### **1.8.4 Limited Power in Mobiles Terminals**

Wireless mobile terminals have power constraints and therefore cannot afford to transmit numerous control messages. The scheduling algorithm must be sensitive to the plight of the mobile terminals as the exchange of information such as queue status, packet arrival times and channel states with the base station in form of control messages can deplete the power in a short time. There must be a trade-off between the complexity of scheduling algorithms and its speed of execution so that delay-sensitive traffic flows can be efficiently transmitted.

### **1.8.5 Bandwidth and Channel Utilization**

The data throughput in wireless networks is a major consideration when scheduling how wireless channels are to be utilized. Scheduling algorithms must eliminate error-prone transmissions that results in waste a of wireless resources.

## **1.9 Problem statement**

The delay-intolerant nature of video traffic has garnered much attention. The extensive research done using scheduling algorithms, however has not considered the option of a single queue priority scheduler. Previous solutions have employed buffer management techniques and where scheduling was used, it was a multi-queue scheduler that was employed. However, I propose a single-queue priority scheduler to reduce the packet loss in the video network by prioritizing the video frames. The packet loss in the network is largely due to buffer overflow.

## **1.10 Research Questions**

This study proposes to answer the following research questions:

- Can scheduling algorithm improve video transmission in WLANs?
- What is the sensitivity of scheduling algorithm efficiency to WLAN nodes?

## **1.11 Research Aim and Objectives**

The aim of the study is to design a scheduling algorithm that will improve video transmission in a WLAN. To achieve the aim, the following objectives were set:

- Propose a workable scheduling algorithm to provide optimal transmission of video traffic in wireless networks.
- Develop an executable methodology for the proposed single-queue scheduler.
- Implement this work on OPNET 14.5 modeller.

## **1.12 Scope and Limitations of Research**

This research will consider only MPEG video type in wireless local area networks (WLAN) also referred to as IEEE 802.11 networks.

## **1.13 Contributions**

The single queue priority scheduler improved the transmission rate considerably and reduced the packet loss rate. Similarly, the buffer overflow was monitored and seen to reduce packet loss by approximately 34%.

## **1.14 Dissertation Outline**

This chapter has introduced the research on the Single-Queue priority scheduler and discussed the QoS parameters. The next chapter examines various scheduling algorithms in detail and outlines their pros and cons. MPEG video type is discussed as it is the video type of choice and the most common video file type transmitted over wireless networks. Chapter 3 discusses the methodology used to put the single-queue priority scheduling algorithm to test, along with the implementation and parameters. The results of the simulations are fully discussed in Chapter 4. The concluding chapter 5 corroborates the research, draws out the conclusions and recommendations for future work.

## **2 Literature Review**

### **2.1 Sources of problems in video transmission**

Past studies have identified various sources of problems in wireless networks. Akyildiz et al. (2007) showed that the difficulty in the delivery of multimedia content through wireless networks was due to unbalanced traffic, resource constraints and variable network connectivity. Cranley and Davis (2005) indicated that the loss in various multimedia traffic can be attributed to the heavily packed and congested network. Cranley and Davis (2005) are of opinion that the video transmission and rendering received by the user is low when the video packets experience delays, lower throughput and jitter.

### **2.2 Solutions to the problems in video transmission**

Some studies have suggested ways of addressing the problems in video transmission. While some studies suggested an increase in network resources, others argue the available resources can be optimized to reduce or fully eliminate the problems.

#### **2.2.1 Increasing Networking Resources**

Henderson, Crowcroft, and Bhatti (2001) proposed specific upgrades in the network infrastructure to reduce congestion in the video transmission network. This will translate to an increased cost but there is no guarantee that congestion will not occur (Tian et al. 2005).

#### **2.2.2 Optimizing Networking Resources**

Most of the previous works on optimizing of video network for better services can be generally grouped into four categories: optimization through multipath video transmission, optimization using priority scheduling, cross layer designs and error

correction (Politis et al. 2008). In the design of SQPS, the weights are chosen based on the importance of the metrics. The deadline has more importance in the SQPS algorithm because more video frames are transmitted before the deadline of each frame is over. The huge frame loss is largely due to the buffer overflow. Next is the priority of the frame that determine how much importance is placed on the type of frame that is transmitted whether it is I, P or B frames. The cost metric is the third optimization criterion used. It tells us how much loss the video end user perceives when some frame types are lost. The cost metric is related to the priority metric in that it uses the priority placed on the frame type to determine the cost.

### **2.2.2.1 Optimization using Multi-path in Video Transmission**

There are various schemes for using multi-path to optimize video transmission. For example, Politis et al. (2008) suggested a recursive distortion prediction model as an efficient multipath video transmission scheme. In this approach, the source and channel were randomized to schedule the packet transmission among the selected multiple paths. Charfi et al. (2007) adopted erasure codes to ensure that a bit stream is protected from errors before it is transmitted over various paths with different reliabilities and capacities. Yousefi et al. (2009), used a score based mechanism to route video from its source to its destination. The path score is calculated based on the properties of the paths and the required QoS. Guan and He (2010) proposed a method of discovering multiple paths with high energy efficiency while Murthy et al. (2007) proposed a more practical way of improving path selection for video transmission by predicting the quality of the link. In their approach, when different video encoding schemes are used, different metrics for multipath computation should also be adopted for use. Bansal et al. (2004) introduced a routing protocol that chooses the most desirable paths from a source to its destination based on the bandwidth in the various links. This novel routing protocol chooses high bandwidth paths by leveraging on the multi-rate ability of IEEE 802.11. This work further reiterates that the minimum hop count as a metric for routing is not adequate. This incompetency is highlighted by Li et al. (2001). However, the multi-path approaches are

resource intensive. In addition, they are not suitable for wireless networks which have limited bandwidth.

#### **2.2.2.2 Optimization using Priority Scheduling**

Some authors proposed the use of priority scheduling to optimize wireless networks. Jun et al. (2010) proposed that the video stream should be separated into image and audio in a bid to assign different priorities in the low bandwidth wireless networks. Hurni and Braun (2008) proposed an adaptive video transmission scheme so that the video source periodically receives network conditions and dynamically does packet and priority scheduling. Lari and Akbari (2010) suggested a packet scheduling algorithm that groups each frame in a group of pictures (GOP) based on its priority. In this approach, there is I, P and B frames and the highest priority is given to I and P frames then the B frames. The higher priority frames are transmitted through optimal paths. Panahi (2010) solved the problem of high packet loss rate by buffering high priority video packets and controlling forwarding rate of the video traffic. Carey et al. (1989) worked on priority in DataBase Management System (DBMS) resource scheduling without considering the cost and disk scheduling. In the HiPAC project also by Carey et al. (1989), the support for timing constraint in databases was implemented but the priority, cost and disk scheduling issues were not considered. Ghandeharizadeh et al. (2003) proposed a single-queue algorithm that is cost-driven for two priority levels of traffic and also meets the deadline of higher priority traffic to increase the throughput of the system.

Goel and Member (2008) have proposed a method to prioritize video frames thereby improving the QoS availed to the users. The priority is assigned based on how important the frame is to the video decoding process. These video frames enjoy more network resources while other traffic is not deprived of network resources. Although the issue of congestion and packet loss were not eradicated completely, the above authors showed that priority scheduling can increase the throughput in a multimedia network and also reduce packet loss rate which is very important for delay-sensitive packets like video.



The SQPS proposed in this study uses the priority scheduling approach to reduce the loss due to buffer overflow in our infrastructure based wireless local area network.

### **2.2.2.3 Optimization using Cross-Layer Design**

More and more studies show that the cross-layer designs (CLD) approach can be used to minimize packet loss in wireless networks. The proposed solution by Goel and Member (2008) tweaks the data-link layer components to achieve a better quality in video streaming without jeopardizing the chances of other less important traffic. This work was implemented using Network Simulator 2 (NS-2). Chen et al. (2008) used a cross-layer technique with path priority scheduling for real-time video streaming over Wireless Sensor Nodes.

With mobile video integrated into medicine where human lives may depend on the continuous streaming of video without any disruption, Garawi et al. (2006) looked into minimizing the packet loss for streaming video in wireless networks. This method proposed by Srivastava and Motani (2005) surveyed different cross-layer designs and argued for its enhancement. The study showed cross-layer designs simply eradicates the communication confines in the layers of the Open System Interconnection (OSI) model to enhance video streaming in wireless networks.

Other methods proposed by using this technique include developing rate adaptation (Moleme et al. 2009) for the efficient streaming of video and other real-time applications. Larzon et al. (1999), in a bid to reduce the loss of multimedia packets, put forward a reformed version of the UDP called UDP-Lite. Since the UDP's checksum safeguards the entire header or loses the whole packet, there is no option for delay-sensitive traffic like video, which prefer packets with errors to the total loss of the packet. UDP-Lite solves this challenge by separating the packets in the UDP header into sensitive and insensitive parts. The sensitive part is discarded when errors occur while the insensitive part is still transmitted and the errors are ignored. This work by Larzon et al. (1999) showed that UDP-Lite efficiently uses the wireless network without increasing the

packet loss ratio, this solution is seen to be incompatible with the original UDP because it will require modifications to interwork.

Kumar et al. (2013) developed a unique cross layer algorithm to guarantee the seamless and continuous transmission of videos. The authors achieved better quality of service compared to other algorithms using the Peak Signal to Noise Ratio (PSNR) as the main metric. The cross layer algorithm developed by these authors is called Multi-Layered Coding with Cross Layer Adaptation (MLC-CLA). Although the cross layer design approach bridges the gap between the Open System Interconnection (OSI) layers, there is no clear-cut standard. This is a major cause of incompatibility and conflict in system protocols.

#### **2.2.2.4 Optimization using Error Correction**

Some studies also used error correction to optimize the WLAN. For example Rehman et al. (2012) strongly support packet prioritization to enhance video streaming while Wang and Zhu (1998) support error control and concealment methods as a better way of transmitting videos from a source to destination.

#### **2.2.3 Enhancement of MAC protocol**

Some studies have also modified MAC protocol to improve video transmission in WLAN. For example, Xiao (2004) used two mechanism-concatenation and piggybacking to solve the overhead problem in the IEEE 802.11 MAC protocol. While the concatenation mechanism combines multiple frames into a single transmission, the piggyback mechanism allows a sender to attach a data frame to an acknowledgement packet so it does not need to vie for the channel again. By using a dynamically tuned backoff algorithm, Cali et al. (2000) obtained enhancement in the capacity of the IEEE 802.11 MAC protocol. The algorithm proposed by Cali et al. (2000) alters the size of the backoff algorithm by using an estimated value obtained by closely observing the channel status.

Bruno et al. (2002) proposed an improvement to the MAC protocol by varying the parameter  $p$  which represents the average size of the contention window that gives a maximum throughput with minimum energy consumption. The backoff interval of the probability persistent (p-persistent) IEEE 802.11 protocol is sampled from a geometric distribution of  $p$ . Shih et al. (2009) recommend a Request-to-send Collision Avoidance (RCA) protocol that uses a pulse-time and data channel to transmit data. The RCA protocol reduces the RTS collisions noticeably when there is high traffic, to improve the throughput of the system. The RCA protocol also eradicates endless retransmissions to free up more bandwidth and it has a lower control overhead than the Distributed Coordination Function (DCF) in IEEE 802.11 MAC.

Cesana et al. (2003) improved the Distributed Coordination Function's (DCF) performance by inserting information about the Signal-to-Interference Noise Ratio (SINR) and received power levels into the Clear-To-Send (CTS) packets. This improvement to the IEEE 802.11 MAC is called the Interference-Aware MAC (IA-MAC). Lin and Liu (2002) proposed the distribution cycle stealing (DCS) mechanism to enhance the performance of IEEE 802.11 DCF using power control and spatial reuse methods. The DCS regulated the transmission power to manage the range thereby creating space for another new communication provided there is no interference.

Ozugur et al. (1999) use connection and time based methods to improve fairness in the IEEE 802.11 MAC protocol. The average contention period or the number of connections is used to calculate the link access probability  $P_{ij}$ . Jiang et al. (2007) explored the hidden and exposed terminals and explored it as a way to increase the fairness and throughput of the IEEE 802.11 wireless network. They proved mathematically the non-scalability of the 802.11 network due to the hidden and exposed terminals and that more network infrastructure does not improve the throughput of the entire WLAN.

Wang and Garcia-Luna-Aceves (2003) put forward a fusion of the sender and receiver-initiated channel access schemes for improving fairness in the IEEE 802.11

MAC protocol. This hybrid solution proves to be very efficient and does not reduce the throughput in the WLAN. Nevertheless, using enhancement of MAC protocol to improve video transmission is a complex approach and requires sophisticated resources.

#### **2.2.4 Performance Evaluation of the Solution**

Some studies have focused on evaluating the performances of the optimizations schemes. Aiyetoro et al. (2012) tested the viability of the M-LWDF and the EXP-PF in supporting video and VoIP traffic with metrics ranging from Packet Loss Ratio (PLR), throughput, fairness and average delay. The network of use is the Long Term Evolution (LTE). Interestingly, a video trace file is used to test the real-time traffic performance under varying user influx. The results show that M-LWDF performed better in spectral efficiency, throughput and PLR while EXP-PF outdid M-LWDF in delay.

Kim et al. (2013) analysed three different scheduling algorithms: Proportional Fair (PF), Modified Largest Weight Delay First (M-LWDF) and Exponential Proportional Fair (EXP-PF) Schedulers. These algorithms consider different speeds of mobile users in relation to how video and voice traffic is transmitted in LTE networks. The scheduling algorithms' performance was evaluated to reflect the PLR for video and voice traffic at different speeds. The results showed that as the number of User Equipment (UE) increased, the PLR also increased. The performance of PF scheduler is greatly affected by the increased UE terminals while M-LWDF and EXP-PF show better and reduced PLR values when video is transmitted.

Ramli et al. (2009) suggests that M-LWDF performs better than Round Robin (RR), MaxRate, PF and EXP-PF in throughput and in increasing the number of users. These algorithms were tested for video transmission and although RR ranked highest in fairness, the M-LWDF did considerably well on the fairness scale. Based on their experiments, the authors recommend M-LWDF as the best packet scheduling algorithm for transmission of video.

A new scheduling algorithm-CABA outweighs benefits of RR, PO and PF in system throughput, fairness and PLR. Lin (2008) has proposed CABA as a worthy replacement and the results show that the PLR due to buffer overflow is greatly reduced. Studies by Kamel et al. (2009) have shown that using a multi-disk architecture evaluation can make the results of the evaluation too ambiguous. They showed that with this approach, one node may create a bottleneck in the network, thereby slowing down the processing capability of the system. They also showed that using a multi-disk architecture can make the results of the evaluation too ambiguous. This is because in a multi-disk architecture, one node may create a bottleneck in the network, thereby slowing the processing capability of the system. Meanwhile, using a single disk will efficiently quantify and compare the one-queue algorithm with the multi-queue algorithm. Shankar & van der Schaar (2007) and Su et al. (2006) investigated the performance of video streaming, considering wireless networks and congestion. Goel and Member (2008) came to the same conclusion as Wang et al. (2006) that video packets lose their quality when subjected to network congestion. Their findings showed the need to prioritize some encoded video frames, which have been identified as the base frame for seamless video streaming to occur.

### **2.2.5 Previous studies on Adaptive Real-Time Internet Streaming Technology at UCT**

Under the Adaptive Real-Time Internet Streaming Technology (ARTIST) project, the University of Cape Town's Electrical department has made efforts on improving the low bandwidth video streaming. For instance, Setongo (2010) studied media plug-in architectures for real-time applications. Media plug-ins allow for enhanced functionality on an existing multimedia application. The author compared different plug-in architectures based on plug-in scalability, threading overhead, average processing speed and programming complexity, and found that GStreamer was the best plug-in architecture for live broadcasting because it had less processing time, less complexity in its programming and more scalability.

Kakande (2010) designed RTP-Lite, a light-weight version of the Real-time Transport Protocol (RTP) to reduce delay and packet loss. The RTP-Lite protocol is used with an open source streaming library over the internet. The results showed that the RTP-Lite protocol experienced very little degradation in packet loss and improvements in the jitter and throughput. Zodi (2011) designed a congestion control protocol for streaming video by coordinating interactions between transmitting nodes. The protocol controls the rate of video transmission based on the network status. The author also used Forward Error Correction (FEC) codes to enhance the performance of the wireless networks by padding the original video packets with the FEC codes, and obtained better quality in video streaming.

Koduri (2011) designed four algorithms to speed up video encoding and maintain good video quality. The algorithms are: Large Diamond Search (LDS), Small Diamond Search (SDS), Small Diamond Hierarchical Search (SDH) and Two-Tier Hierarchical Search (TTHS) algorithms. This study sought to design algorithms showing that the algorithms were more than 75% faster than existing algorithms without downgrading the video quality. Lastly, Lubobya (2011) optimized the Hadamard transform and Integer Discrete Cosine Transform (IDCT) used in encoders for video compression. The results showed that the optimization improved computation time speed-up by approximately 45%. The present study aims at further development of the algorithm concepts of these previous studies.

## 3 Methodology

### 3.1 Single-Queue Priority Scheduling Algorithm (SQPS) in WLAN

The study introduces the Single-Queue Priority Scheduling Algorithm (SQPS) in a Wireless Local Area Network (WLAN). The SQPS is an algorithm developed to reduce the Packet Loss Rate (PLR) in a Wireless Local Area Network (WLAN). The PLR is the ratio of the packets lost to the total packets transmitted in the wireless network. With the increase in the transmission of the multimedia traffic (voice, video) as forecasted by Cisco Visual Network Index (2013-2018), there is higher demand on the network resources. The SQPS is one of the oldest methods used in the packet prioritization. It has been used as early 1992 (Kanumuri 2006). Pancha and El Zarki (1992) gave two categories of packet prioritization- data partition and layered coding methods. The data partition method assigns priorities after compressing the data while the layered coding picks a base layer that will be used to decode the entire video. Ghandeharizadeh et al. (2003) used a metric-based method similar to the SQPS in scheduling multi-priority requests with active buffer management. This method was called a cost-driven disk scheduler.

The SQPS algorithm uses three metrics- deadline, priority and cost with weights to prioritize the video frames. The metrics are combined linearly to get an SQPS value ( $S_n$ ). The  $S_n$  value is used to arrange the frames from the smallest to the largest in readiness for transmission. The deadline is the time within which the frame must be transmitted before it is dropped. The deadline metric is the most important metric in the SQPS algorithm and it is assigned the biggest amount of weight. Next is the priority which is calculated based on the importance of the frame. Since we are making use of the MPEG video, I assigned importance based on the I, P and B frames in that order. The third metric is the cost which is related to the priority. The cost is the amount of loss

incurred if the frame is dropped. This metric is assigned the least amount of weight in the SQPS algorithm.

Static weight are assigned to each metric and the SQPS value ( $S_n$ ) is calculated. For this research, the weights assigned to the Deadline, Priority and Cost are 0.7, 0.2 and 0.1 respectively. The equation below is a linear combination of how the  $S_n$  value is derived.

$$S_n = 0.7D_n + 0.2P_n + 0.1C_n$$

Where  $D_n$  is the deadline,  $P_n$  the priority and  $C_n$  the cost of frame  $n$ .

## 3.2 Metrics in SQPS

### 3.2.1 Deadline

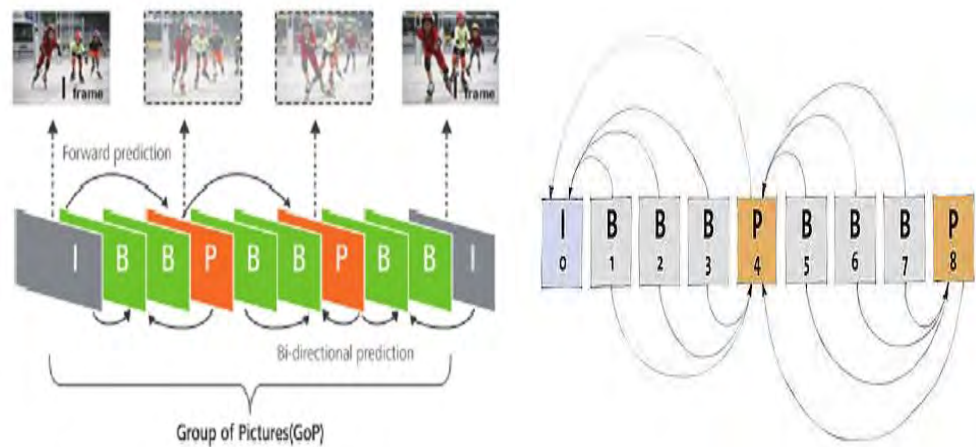
The Deadline  $D_n$  is taken as the absolute time by which the video frame type must be serviced. Any failure to transmit this video before the deadline elapse will nullify it. This is one of the major causes of video loss that reduces the quality of experience perceived by the consumers. The Deadline  $D_n$  is assigned a weight of 0.7 as the most important metric in the SQPS.

### 3.2.2 Priority

The video trace is prioritized by the type of frame to be serviced. The importance of the various frame types is considered as the priority  $P_n$ . This research makes use of the Motion Pictures Expert Group (MPEG) video frame. It has three types of frames known as the  $I$ ,  $P$  and  $B$  frames as seen in Figure 3.1 below.



- **I-Frame:** The **I**ntra frames are also known as the base frames. Intra frames can be decoded independently of any other frames. They have the highest priority.
- **P-Frame:** The **P**redicted frame only stores the difference in image from the frame immediately preceding it.
- **B-Frame:** The **B**idirectional frame is similar to P-frames, except they can make predictions using both the previous and future frames.



**Figure 3.1: An MPEG Video showing I,P,B Frames.**

### 3.2.3 Cost

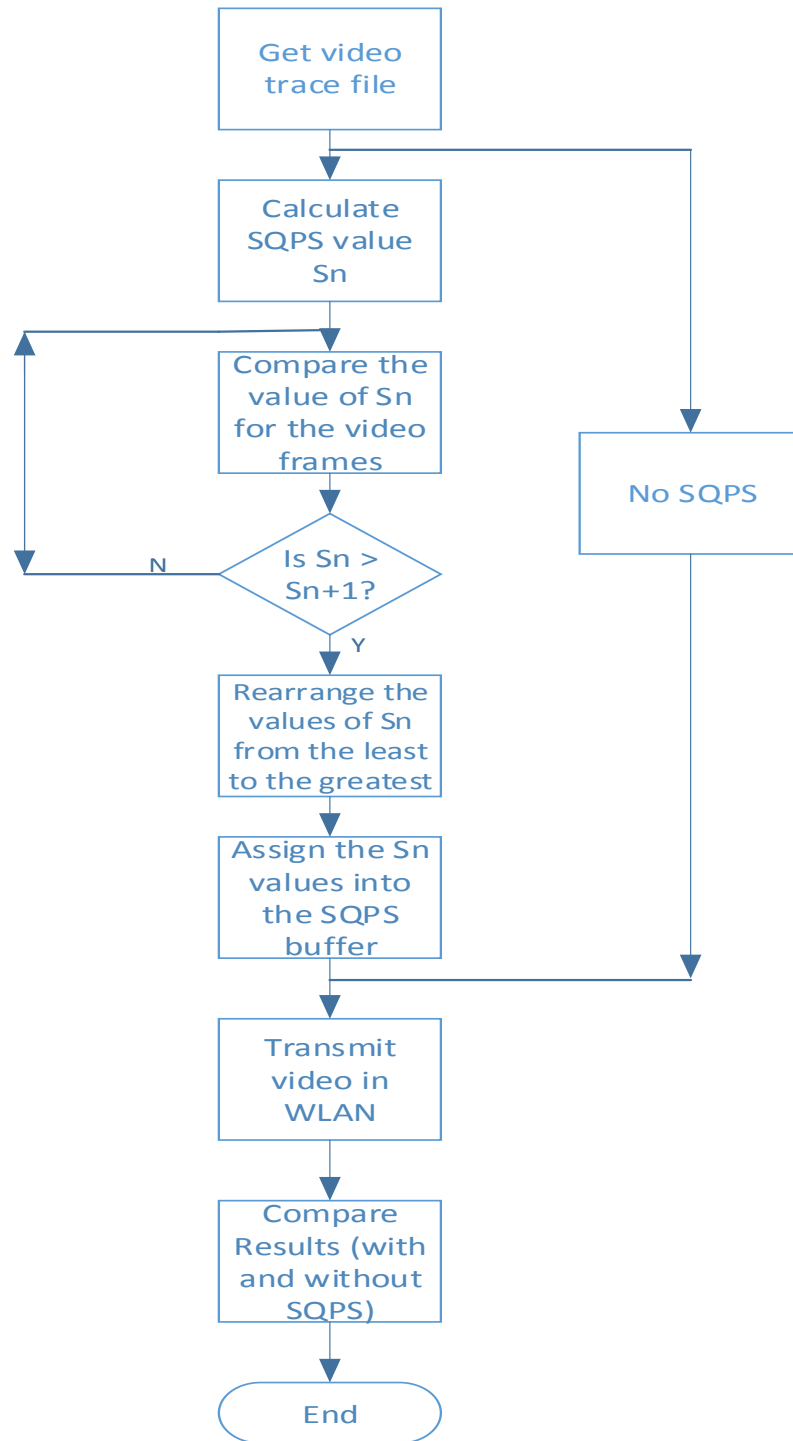
The cost metric  $C_n$ , accounts for the value lost by the video consumer when the SQPS fails to meet the deadline. The cost is closely related to the priority and it is assigned a weight of 0.1 in the SQPS (Ghandeharizadeh et al. 2003).

## 3.3 SQPS Operation

The steps below outline how SQPS works:

- 1) The SQPS gets the video trace file(s).
- 2) The video traffic that does not utilize the SQPS algorithm goes through the No SQPS loop. This is important for comparing the simulation results with and without SQPS algorithm.
- 3) The SQPS value  $S_n$  is calculated.
- 4) The  $S_n$  values of the frame types are compared (i.e. Is  $S_n > S_n + 1$ ).
- 5) Rearrange the trace file(s) using the  $S_n$  values and arranged from the least to the greatest.
- 6) The new trace file is fed into the buffer and transmitted in the WLAN.
- 7) Compare results of traffic with and without SQPS.

A flowchart of how SQPS works is shown in Figure 3.2

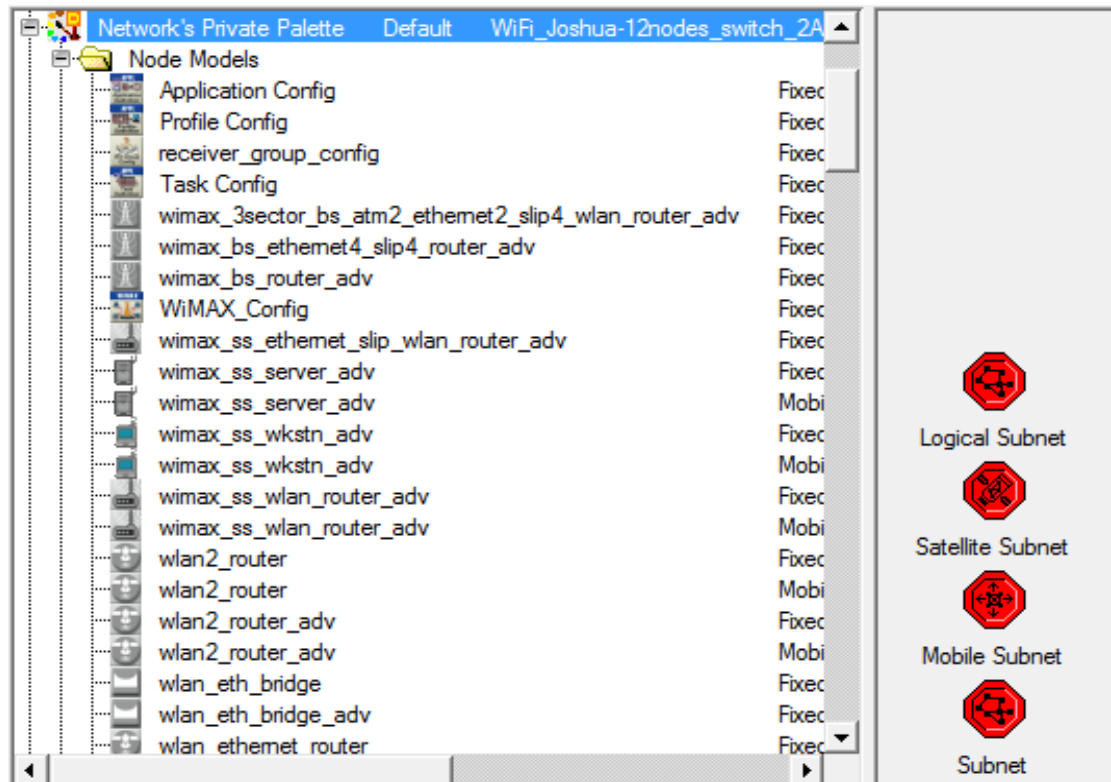


**Figure 3.2: A Flowchart of the Single Queue Priority Scheduler (SQPS) system**

### **3.4 Optimized Network Engineering Tool (OPNET)**






The Optimized Network Engineering Tool (OPNET) version 14.5 was used for all the simulations reported in this study. The OPNET simulator is a discrete event simulator commonly used for research and development of communication networks. Similar to any discrete event simulator, OPNET is an application that has programmed the behaviour of a complex network system as an ordered sequence of well defined events (precise changes in the system's state at a specific time) using high-level programming languages. It has three hierarchical domains, namely: Network, Node and Process domains Lu & Yang (2012).

The Network Domain represents the nodes and the linking objects (see Fig. 3.3). The nodes are the network devices e.g. server, switches, workstations, routers etc. The links represent the point-to-point links used to connect the network devices. There are many network components in the network domain. The ones used for the present study are shown and described in Table 3.1.

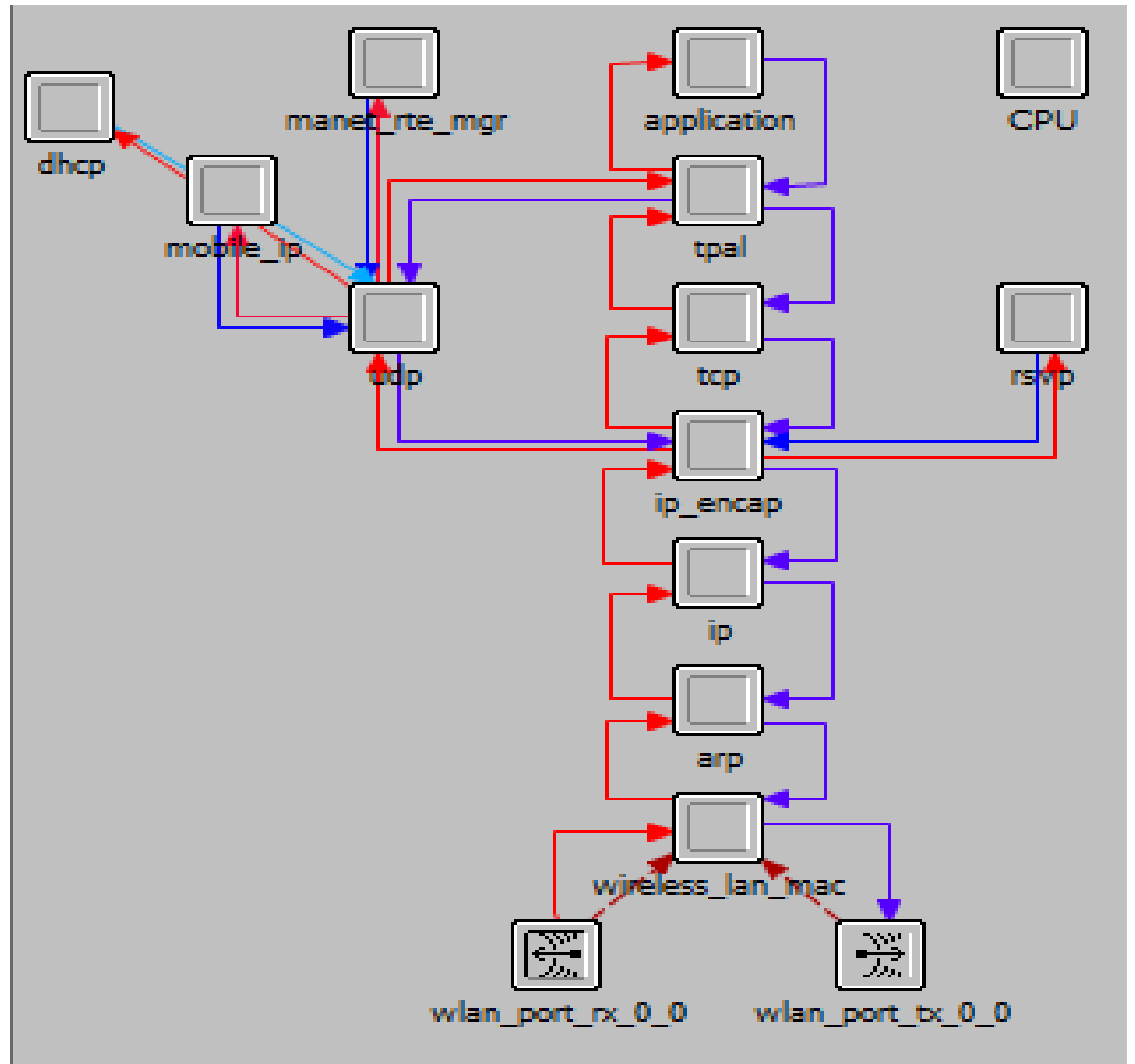


**Figure 3.3: Network domain showing some network devices.**

**Table 3.1: Identification and description of network components used in the study**

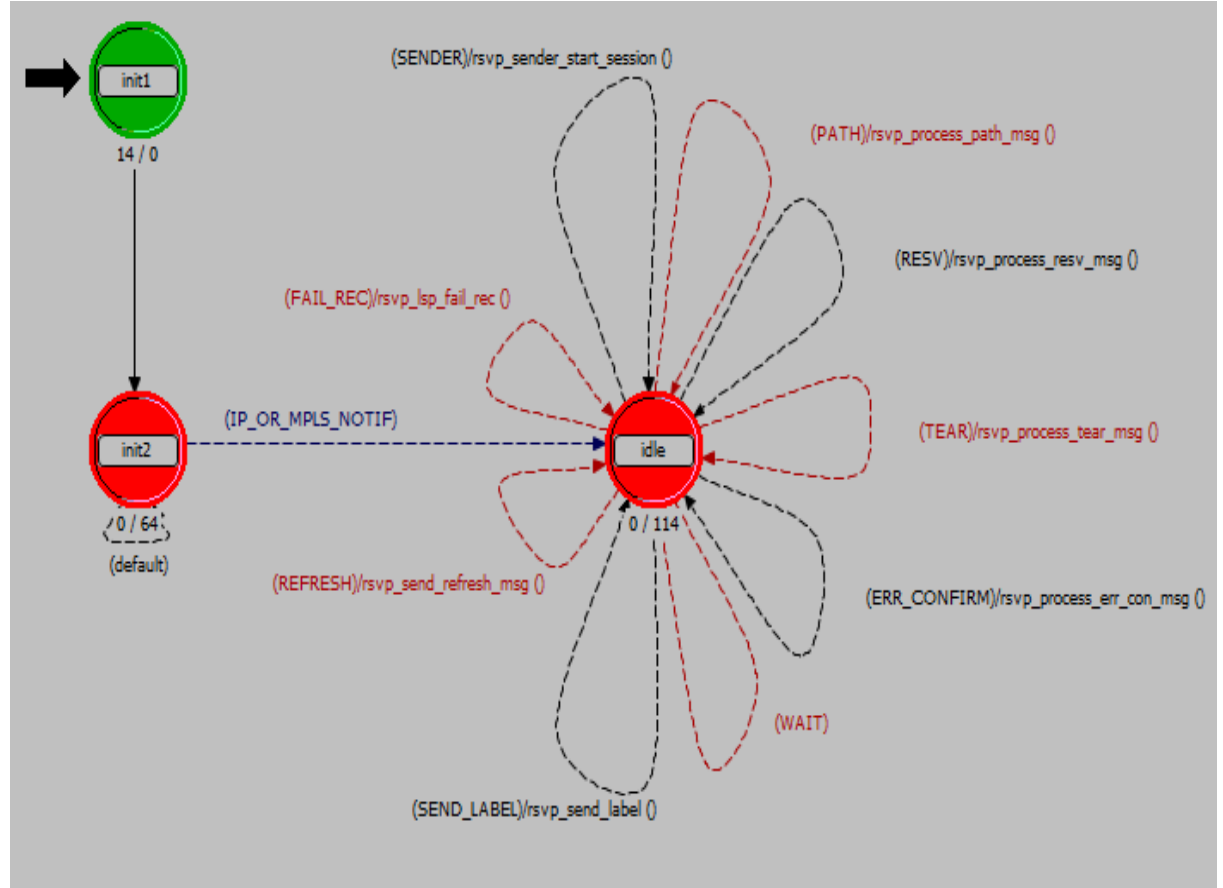
Component	Name	Description
	Wireless Station	This is the mobile node or workstation that the user interacts with.
	Ethernet Switch	The switch is used to connect the Access Points (AP) together.
	Wireless router	The wireless router is an access point that can also connect wirelessly with other.
	Application Config	Defines and specifies the types of application that runs in the network.
	Profile Config	It bears the specific profile of application type.

The Node Domains are the basic building blocks that include the processors, transceivers and queues (see Fig. 3.4). They also contain interfaces that run between modules e.g. the packet streams and statistic wires. While the transceivers are node interfaces, the processors are fully programmable via the process model and the queues are responsible for buffering and managing data packets.



**Figure 3.4: Node domain showing some processors and interfaces.**

The Process Domain consists of the state transition diagrams, C/C++ codes, kernel procedures and state variables (Fig. 3.5). A process is said to be an instance and can dynamically create child processes and respond to interrupts.



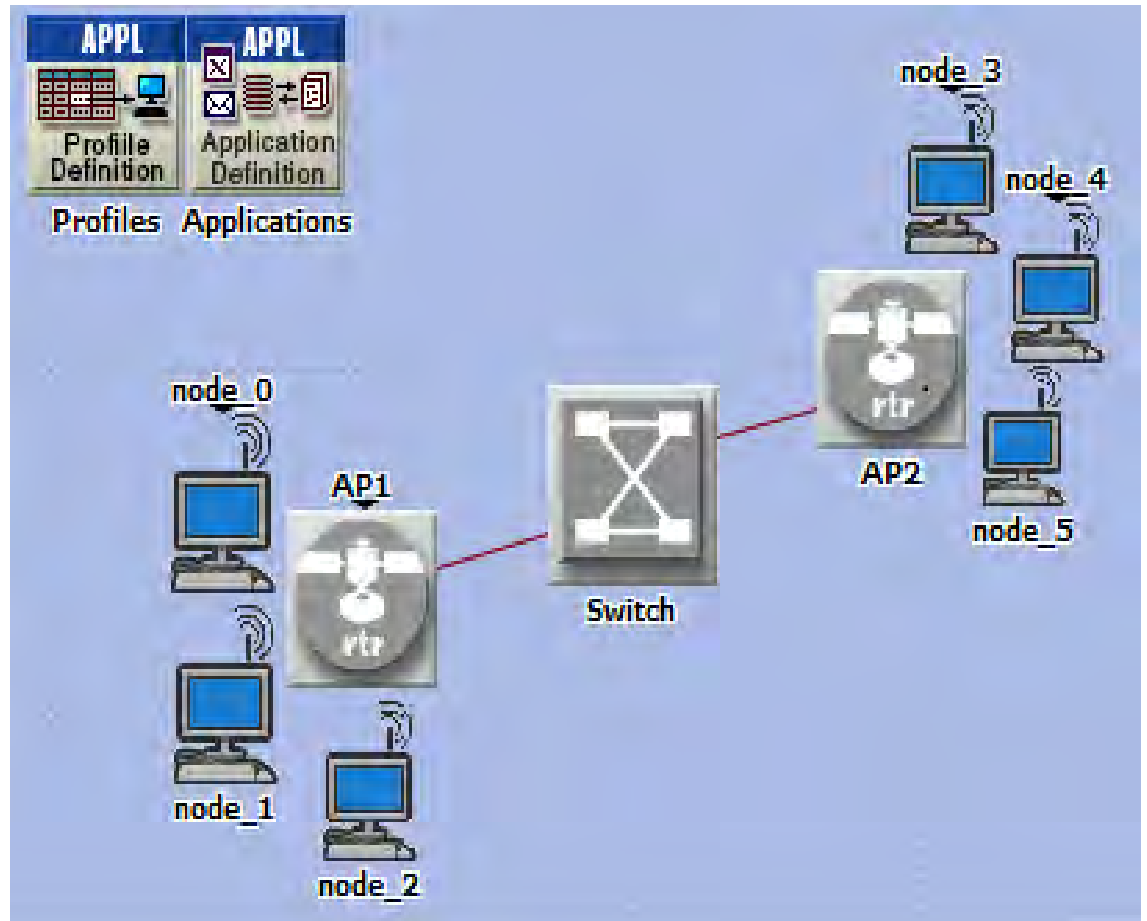
**Figure 3.5: Process domain showing a state transition diagram.**

### 3.5 The Control Simulation

The control simulation for this study comprises of a wireless network of six mobile wireless stations, two access points and a switch were setup as shown in Figure 3.6. There were three mobile stations attached to each access point (AP). The switch is connected to AP1 and AP2 via 100BaseT lines. There was also the applications and network profiles setup to include the type of traffic that passed through the WLAN. A live video trace file (*trace.csv*) was downloaded from the <[www.trace.eas.edu](http://www.trace.eas.edu)> site (Seeling et al. 2012). The parameters of the video trace are shown in Table (3.2). The trace file is transmitted in the WLAN as the test case, simulated and the results were collected for 30minutes. APs 1 and 2 were configured as Base Stations and linked to one another. The



video trace file was thereafter rearranged using the SQPS algorithm. The resulting file generated a new video trace file (SQPS\_trace.csv) that was again transmitted into the WLAN. The simulation again ran for 30minutes and new results were collected to show the impact of the SQPS.



**Figure 3.6: Six-node wireless local area network (WLAN).**

**Table 3.2: The parameters of the video trace used in all the simulations.**

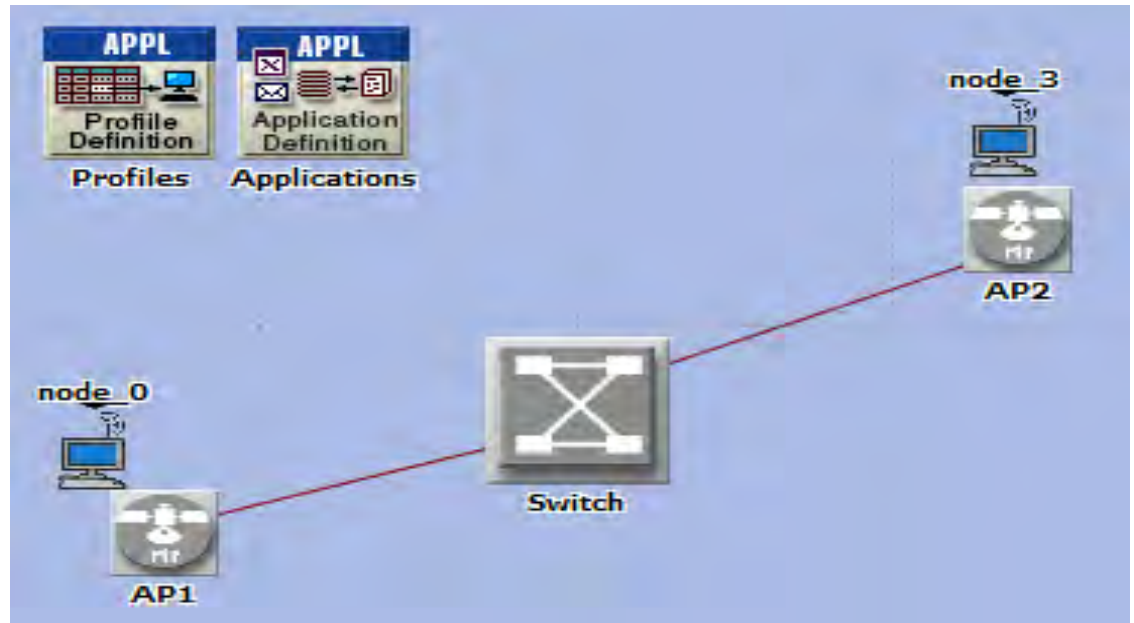
<b>Parameters</b>	<b>Value</b>
Sequence	Elephants Dream
Resolution	352X288
Frames per Second (fps)	24
Encoder	JSVM (9.15)
Encoding type	Main (Level 2.1)
GoP pattern	G16B15
Quantization parameters (I,P,B)	48, N/A, 50

**Table 3.3: The parameters of the application, profile and WLAN setup.**

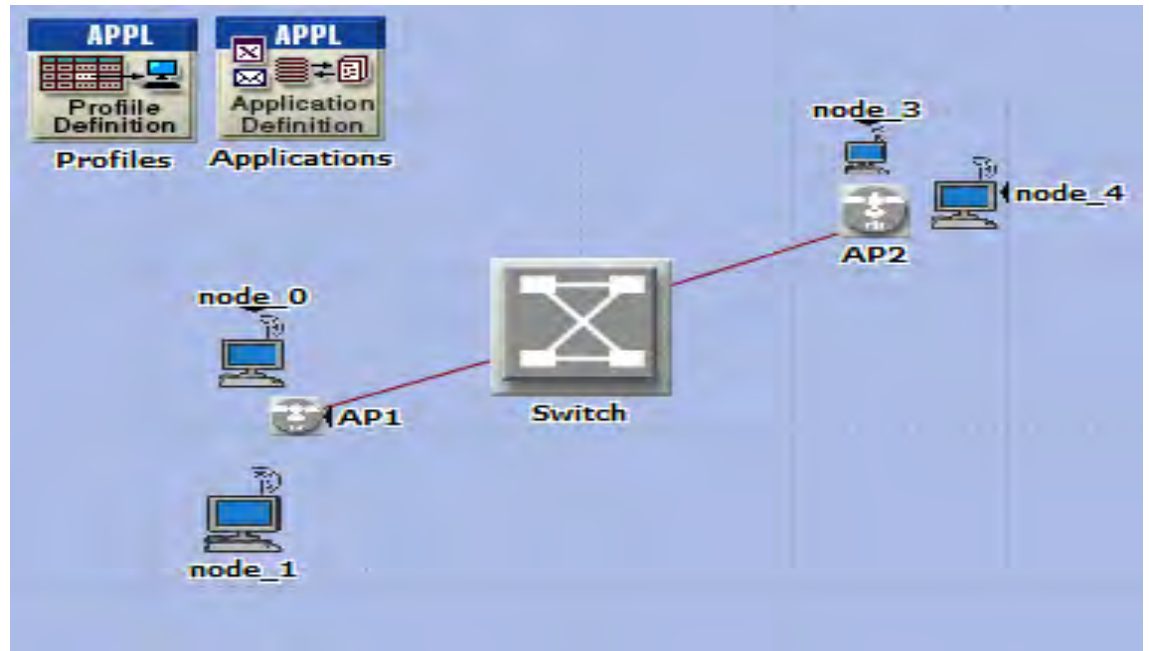
<b>Parameters</b>	<b>Value</b>
Access Point Functionality	Enabled
Physical Characteristics	Direct Sequence
Data Rate (bps)	11Mbps
Transmit Power (W)	0.005
Buffer Size (bits)	256000
Packer Reception Power Threshold (dBm)	-95
AP Beacon Interval (secs)	0.02
Incoming&Outgoing Stream Frame Size Type	Scripted (SQPS_trace)
Application Name	Video Conferencing (Heavy)

### 3.6 The Sensitivity Simulation

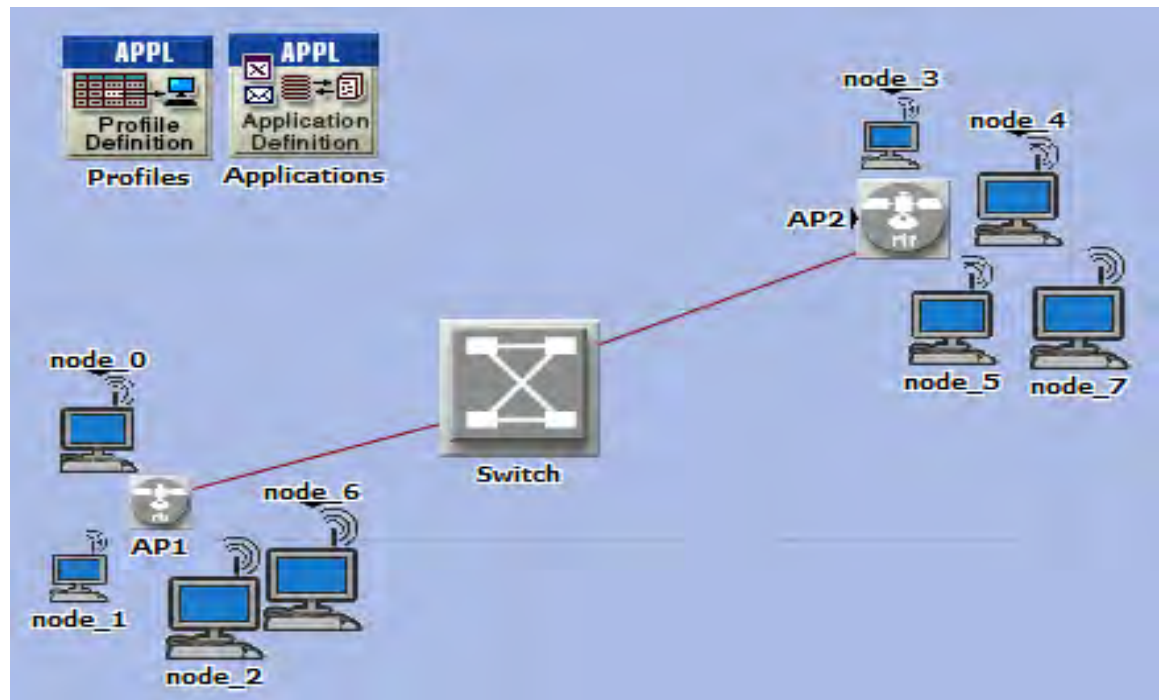
Five sensitivity simulations were performed in order to investigate the influence of WLAN nodes on the video transmission. The set-ups of the sensitivity simulations are the same as those for the control simulation, except that they use a different number of WLAN nodes as shown in Figures 3.7 to 3.11.



**Figure 3.7: Two-node wireless local area network (WLAN).**



**Figure 3.8: Four-node wireless local area network (WLAN).**



**Figure 3.9: Eight-node wireless local area network (WLAN).**

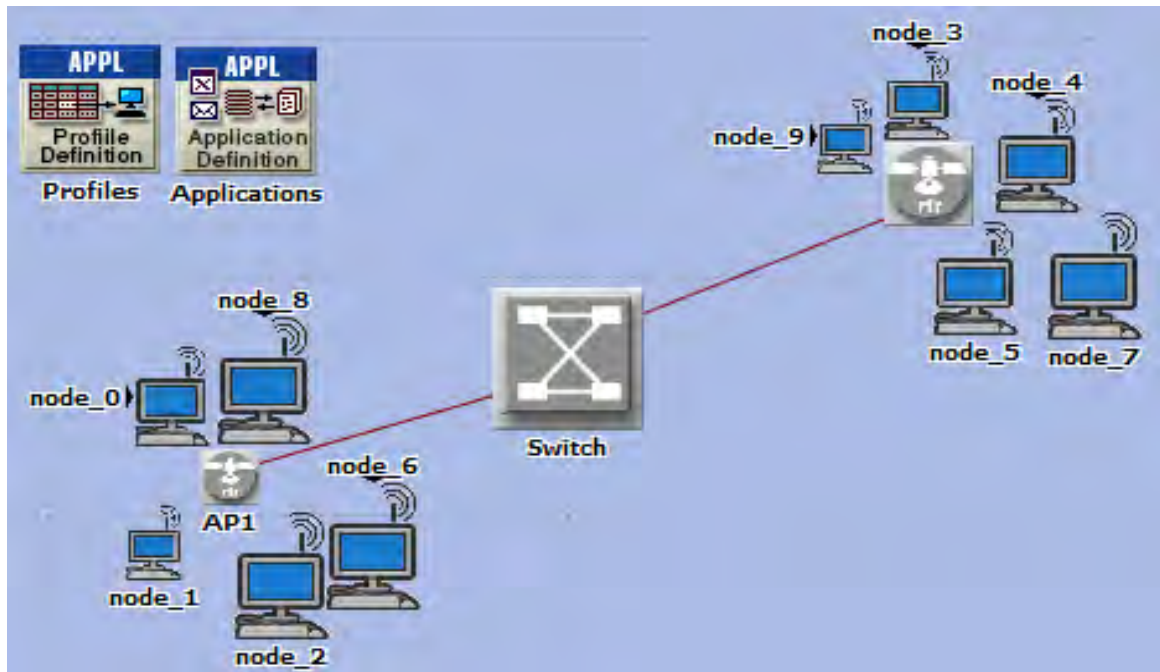


Figure 3.10: Ten-node wireless local area network (WLAN).

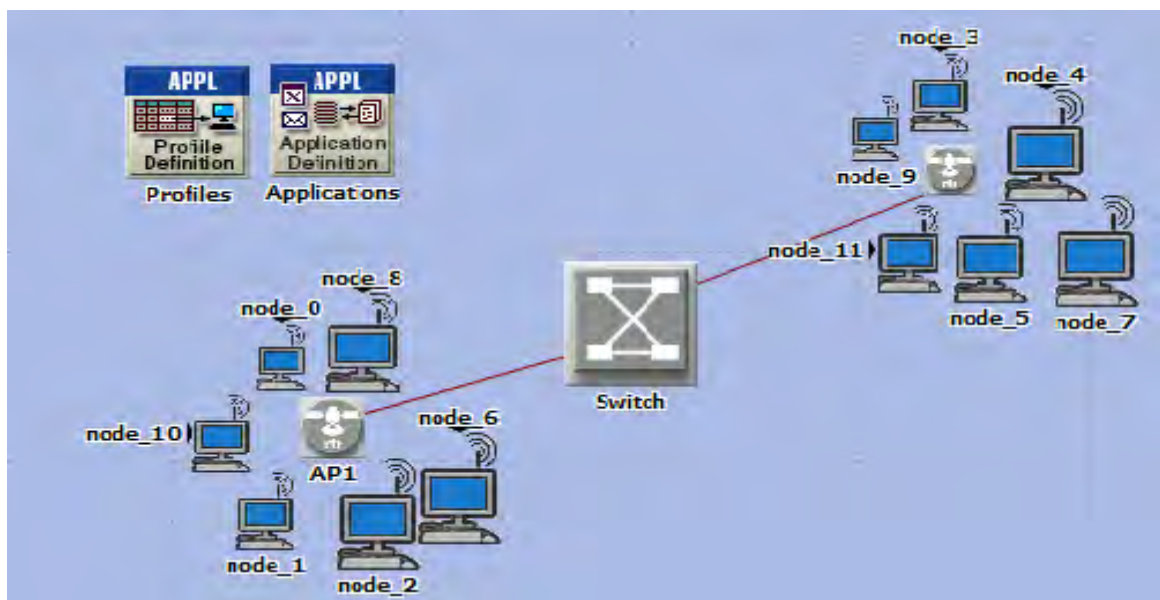


Figure 3.11: Twelve-node wireless local area networks (WLAN).

## 4 Result and Discussions

This chapter discusses the results of the all control and sensitivity simulations used in the thesis. The control simulation describes the characteristic of the load and buffer overflow during the WLAN transmission, and quantifies how the incorporation of SQPS algorithm reduces the buffer overflow. The sensitivity simulation describes how the increase in WLAN nodes influence the characteristics of the load and buffer overflow, as well as its effect on the efficiency of SQPS algorithm.

### 4.1 Control Simulation

This section presents the summary of the results obtained for the control simulation. Figure 4.1. presents the average values of the load and the buffer overflow with and without SQPS algorithm. In the control simulation, the load attains an average data value of 11.8Mb at 4.5minutes. The load continues to increase and reaches a peak average data value of 18.4Mb at approximately 28 minutes.

Without SQPS algorithm, the buffer retains all data until about 3 minutes into the simulation where 0.25Mb was dropped due to buffer overflow. The loss of video packets in the system increased as the load increased and reached a peak average data value of 8.13Mb at about 28minutes.

The results of the buffer overflow with SQPS algorithm show that there is improvement in the video transmission system. The buffer dropped only 0.003Mb of video data in approximately 3 minutes of the simulation. Generally loss of video packets due to buffer overflow in the system is seen to increase as the load increases and reached a peak average data value of 5.82Mb at 28 minutes.

In addition, without SQPS algorithm, the Packet Loss Ratio (PLR) in the WLAN is approximately 43%; but, with the SQPS algorithm, the PLR reduces to 15%. In the first 3 minutes, the load transmits 4.5Mb of video data. The buffer overflow without SQPS

loses 0.81Mb (about 18%) of the total load, while the buffer overflow with SQPS algorithm only losses 0.03Mb (approximately 0.09% of the total load). Hence, the efficiency of SQPS algorithm is over 95% in the first three minutes of the video transmission. However, the efficiency drops to 29% towards the end of the simulation. This is due to the saturation of the buffer as the load increases in the wireless network.

The implementation of SQPS algorithm in WLAN reduces the buffer overflow because the arrangement of the video frames in SQPS algorithm enables the WLAN to send more videos frames before the system reaches congestion. SQPS used a prioritization scheme for video frames based on the metrics- deadline, priority and cost. The prioritized video frames I, B and P were scheduled to be transmitted based on the SQPS value generated from a linear combination of the metrics (deadline, priority and cost). The SQPS value generated was then used to arrange the video frames from the least to the greatest. The systematic arrangement and prioritization of video frames before transmission ensures that very important video frames (e.g. I-frame) will be transmitted before the deadline is due. Subsequently, video frames with lower importance are queued or transmitted provided the deadline of higher priority frames has not expired. Wireless networks are prone to congestion because of variable network connectivity, resource constraint (e.g. low bandwidth), high packet loss rate and high delay latency. SQPS gains an upper hand when it is able to adequately prioritize and transmit many video frames before congestion occurs in the network.

However, the efficiency of the SQPS algorithm drops because the SQPS algorithm like its counterpart depends on network traffic intensity, there is bound to be congestion in the WLAN due to resource restraints. The SQPS simply strives to transmit more video frames before it encounters the resource restraints. When filled to capacity, the buffer is responsible for queuing ready-to-be-serviced video frames drops video frames, and the efficiency of the SQPS drops as a result.

The results of the control simulations suggest that seamless video streaming in wireless networks is subject to the packet loss. However, the video frame prioritization and scheduling by SQPS algorithm can reduce the packet loss rate in a video streaming network. Hence, with the same resources, the users can achieve more with a scheduling algorithm like the SQPS, since video traffic is considered highly delay sensitive.

## **4.2 Sensitivity of the transmission to number of nodes in WLAN**

An increase in the WLAN nodes influences the average values of the load within the simulation period. Hence, there is a linear relationship between the number of nodes in the WLAN and the average data values of the video traffic load. The peak load increases with the number of nodes. The average values of the peak load is 7.1Mb in a 2-node WLAN (Fig. 4.4), 13.4Mb in a 4-node WLAN (Fig. 4.7), 18.4Mb in a 6-node WLAN (Fig. 4.1), 23Mb in an 8-node WLAN (Fig. 4.10), 27.1Mb in a 10-node WLAN (Fig. 4.13), and 31Mb in a 12-node WLAN (Fig. 4.16). The total load transmitted by the WLAN increases as the number of workstations increased.

The change in number of nodes in the WLAN (without SQPS) also alters the buffer overflow. As the number of the WLAN node increases, the buffer overflow also increases. For instance, the average peak data value for the buffer overflow is 0.24Mb in 2 nodes WLAN (Fig. 4.4), 4Mb in 4 nodes WLAN (Fig. 4.7), 8.1Mb in 6 nodes (Fig. 4.1), 12.2Mb in 8 nodes (Fig. 4.10), 16.2Mb in 10 nodes (Fig. 4.13), and 20Mb in 12 nodes (Fig. 4.16).

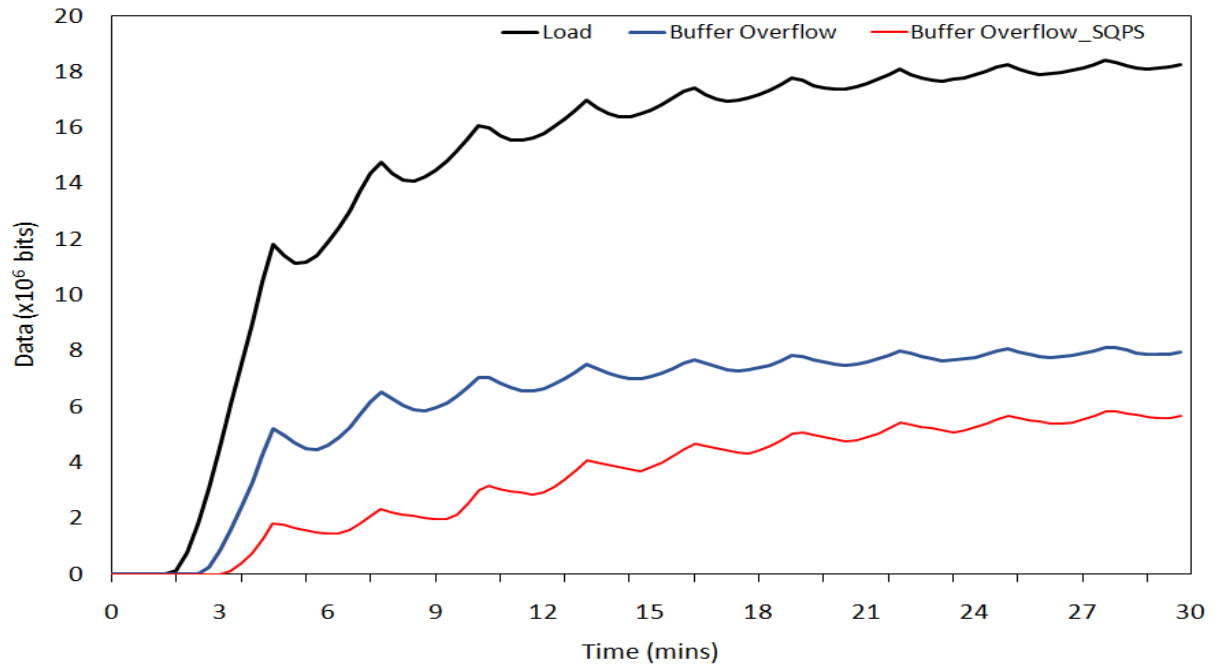
The efficiency of SQPS algorithm varies with the number of nodes in the WLAN. In the 2-node WLAN (Fig. 4.4 - 4.6), the PLR of buffer overflow with SQPS is approximately 0.002%, even though packet loss ratio of the buffer overflow without SQPS has a peak of 2.8%. Hence, the efficiency of the SQPS algorithm is approximately 99.9% in a 2-node system throughout the simulation period. This can be attributed to a



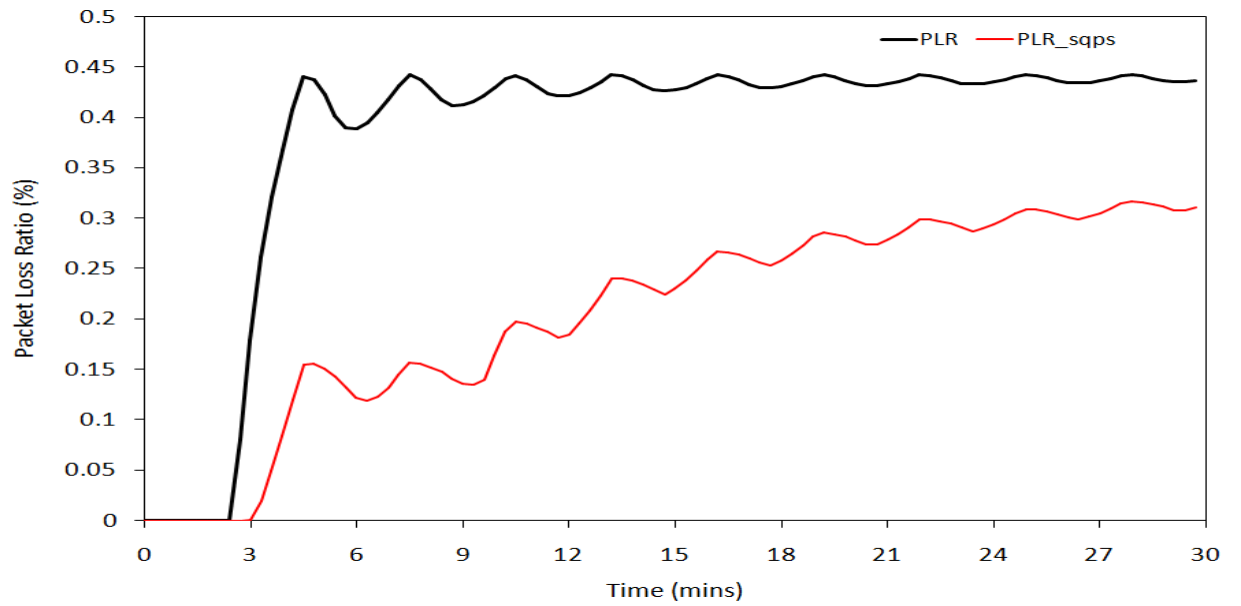
small load and few systems involved in the transmission and receipt of video frames. In the 4-node system (Figures 4.7 - 4.9), the PLR with SQPS did not exceed 9% throughout the simulation compared to the PLR without SQPS that rose to 30%. Hence, the average efficiency of SQPS algorithm is over 80% in the 4-node system.

In the 6-node system (Figures 4.1 - 4.3), the PLR with SQPS recorded 32% throughout the simulation as against the PLR without SQPS reaching 44%. Hence, the average efficiency of SQPS algorithm is over 47% in the 6-node system. In the 8-node system (Figures 4.10 - 4.12), the PLR with SQPS did not exceed 44% throughout the simulation compared to the PLR without SQPS that reached 53%. Hence, the average efficiency of SQPS algorithm is over 33% in the 8-node system.

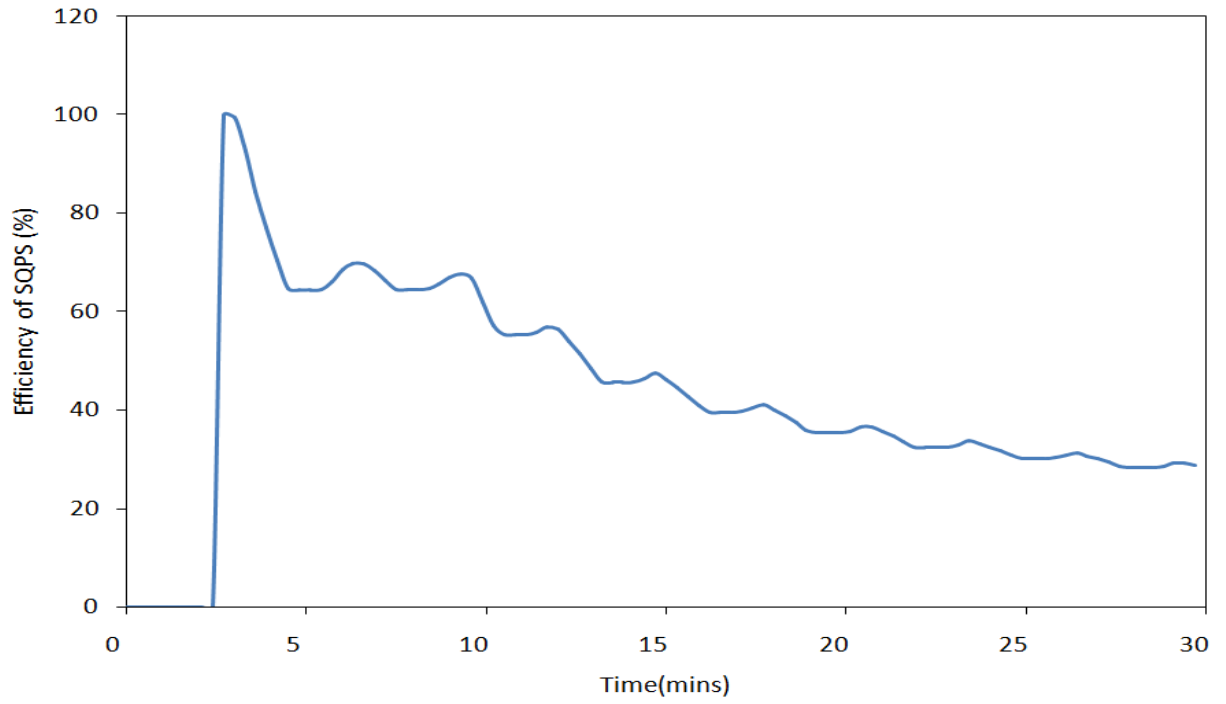
In the 10-node system (Figures 4.13 - 4.15), the PLR with SQPS did not exceed 53% throughout the simulation as against the PLR without SQPS reaching 60%. Hence, the average efficiency of SQPS algorithm is over 26% in the 10-node system. In the 12-node system (Figures 4.16 - 4.18), the PLR with SQPS did not exceed 59% throughout the simulation compared to the PLR without SQPS that reached 65%. Hence, the average efficiency of SQPS algorithm is more than 21% in the 12-node system.



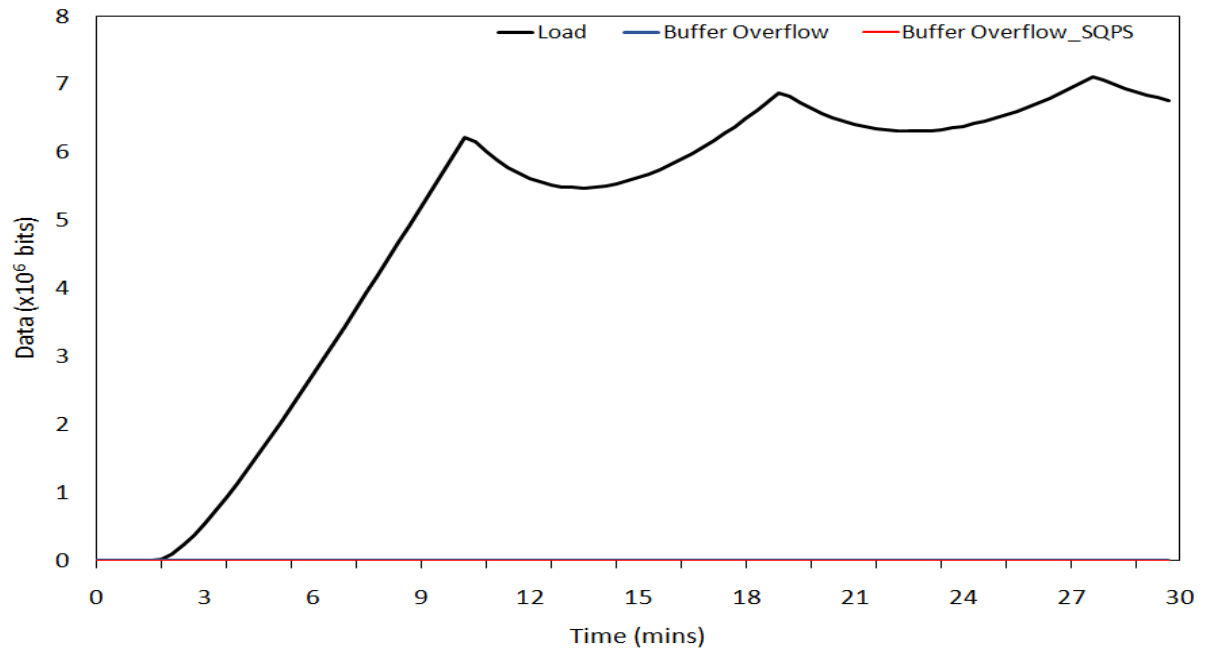
**Figure 4.1:** Average load and buffer overflow with and without SQPS (Six-nodes).



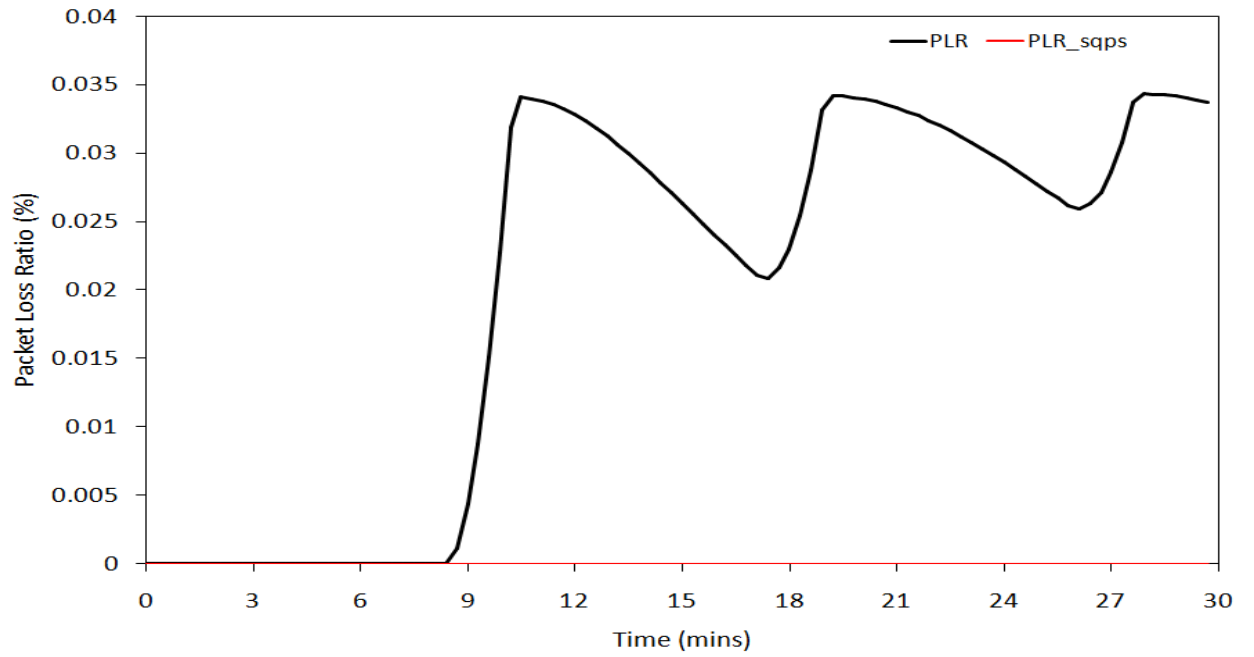
**Figure 4.2:** Average PLR with and without SQPS (Six-nodes).



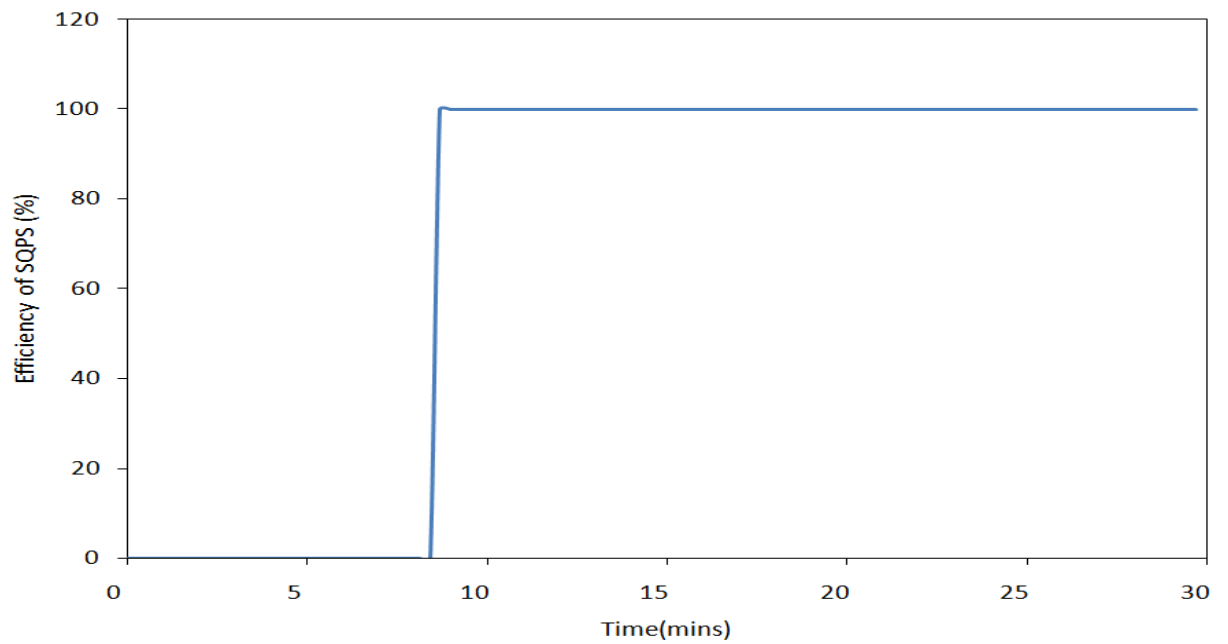
**Figure 4.3:** Average efficiency of the SQPS (Six-nodes).



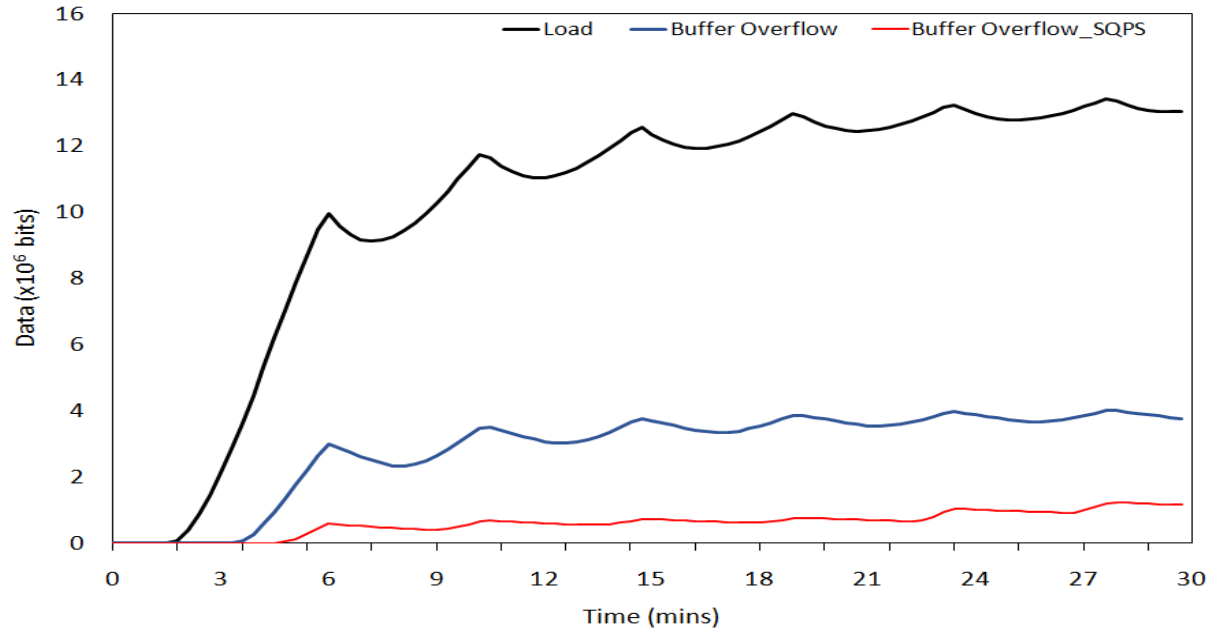
**Figure 4.4:** Average load and buffer overflow with and without SQPS (Two-nodes).



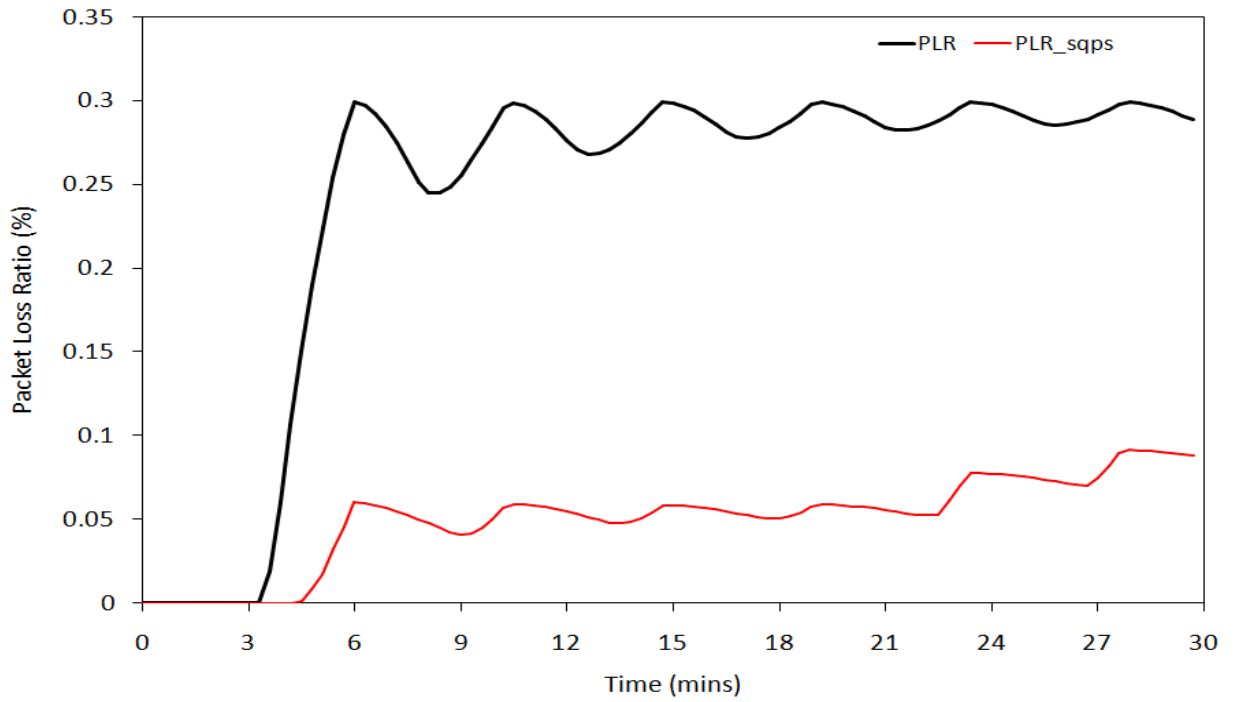
**Figure 4.5:** Average PLR with and without SQPS (Two-nodes).



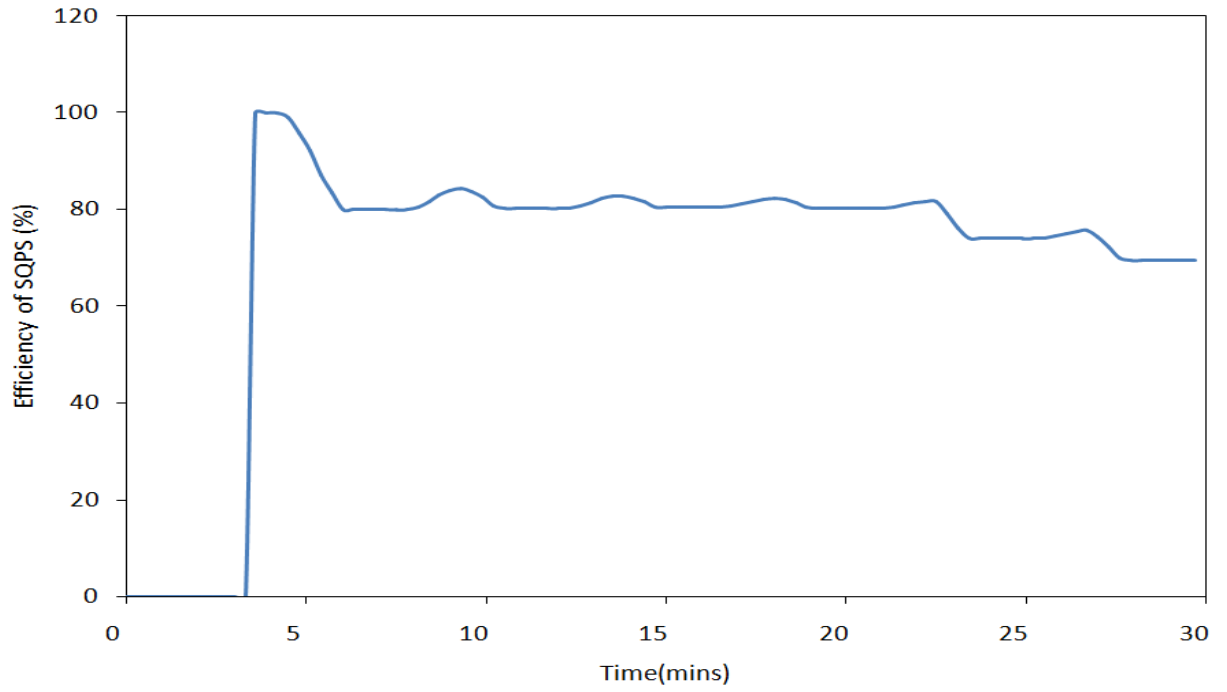
**Figure 4.6:** Average efficiency of the SQPS (Two-nodes).



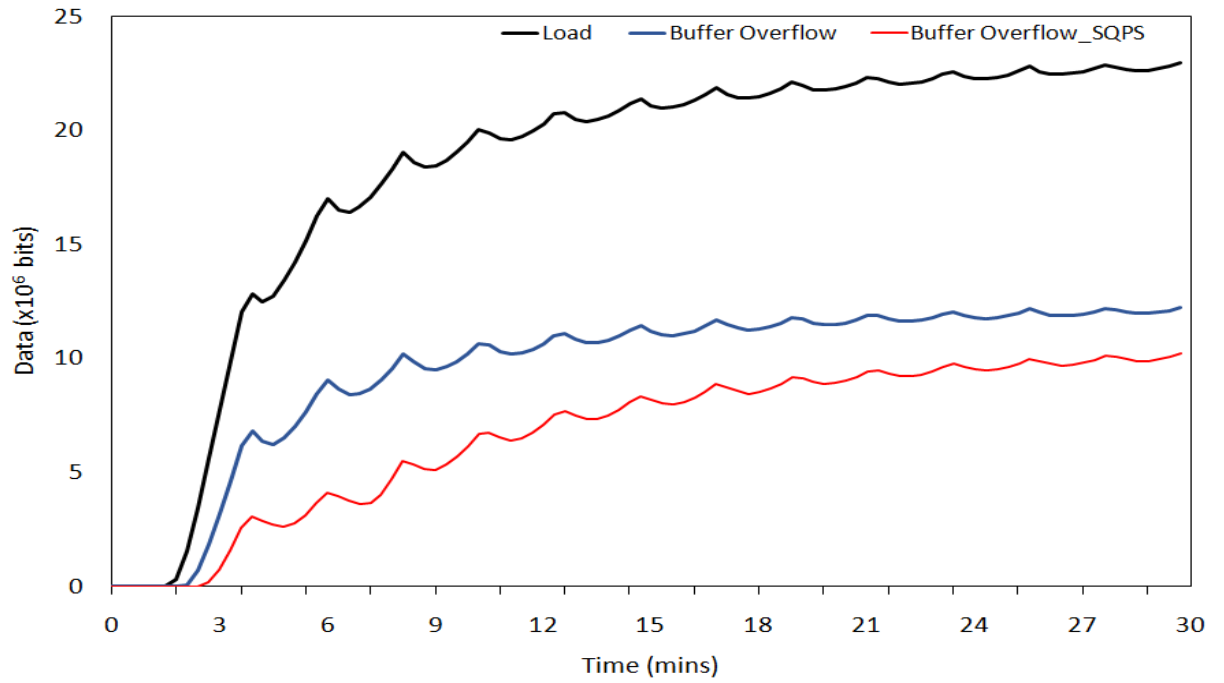
**Figure 4.7:** Average load and buffer overflow with and without SQPS (Four-nodes).



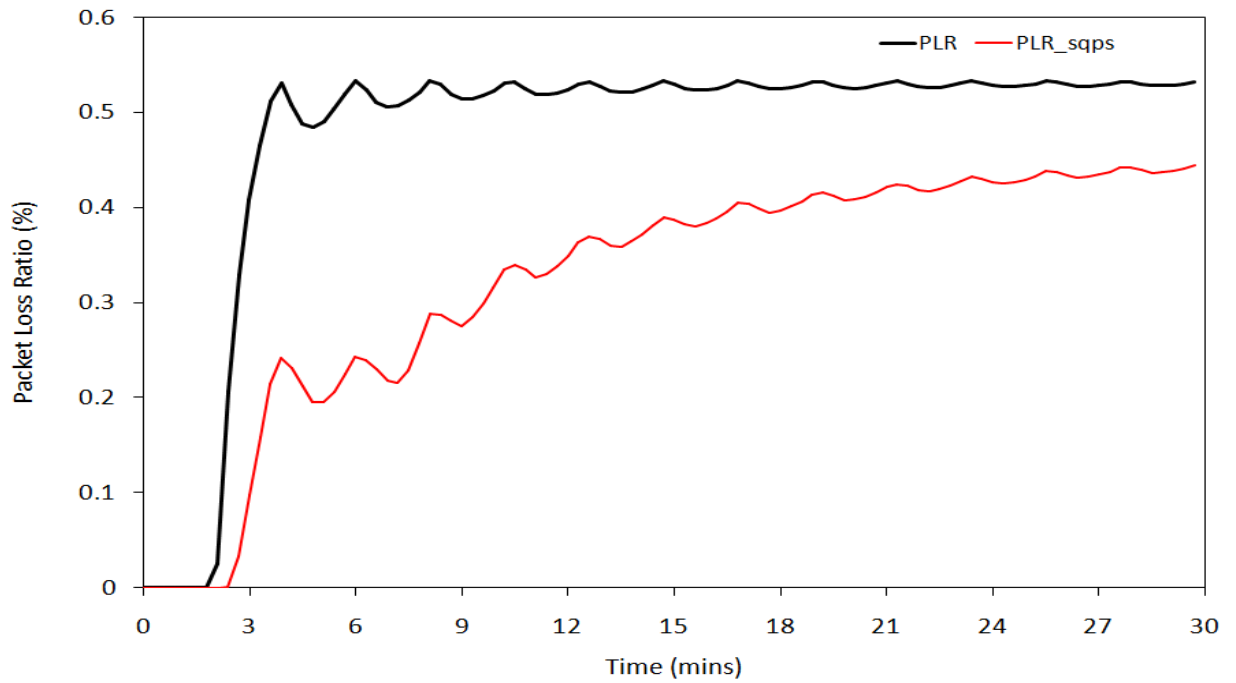
**Figure 4.8:** Average PLR with and without SQPS (Four-nodes).



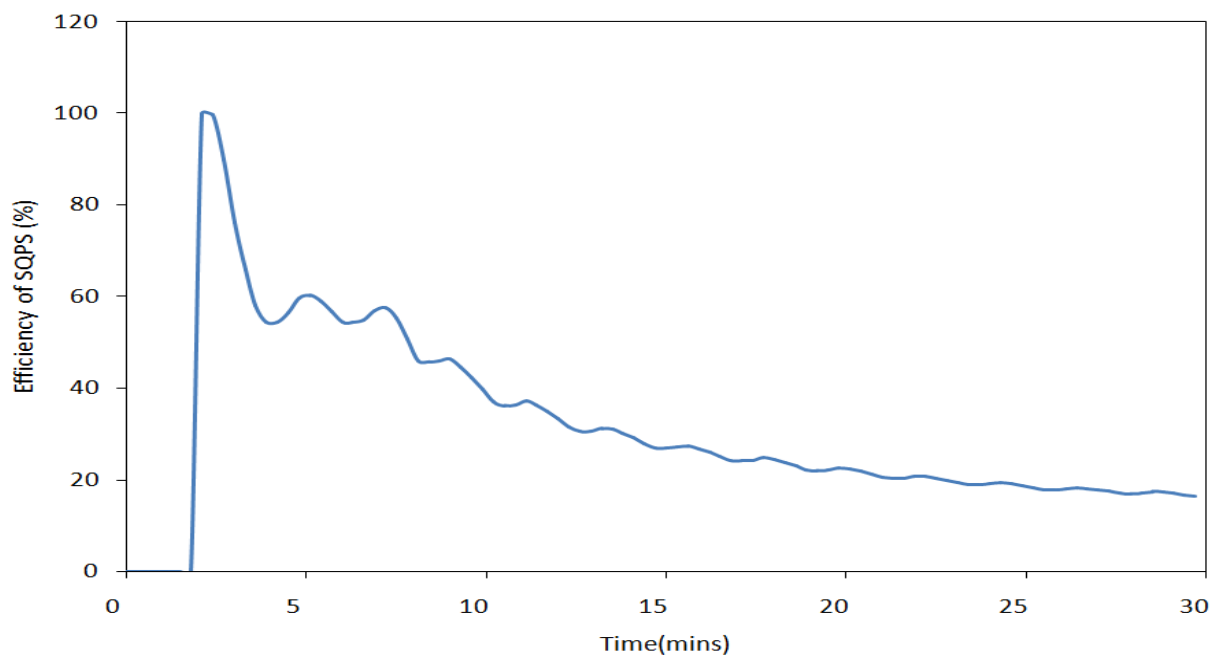
**Figure 4.9:** Average efficiency of the SQPS (Four-nodes).



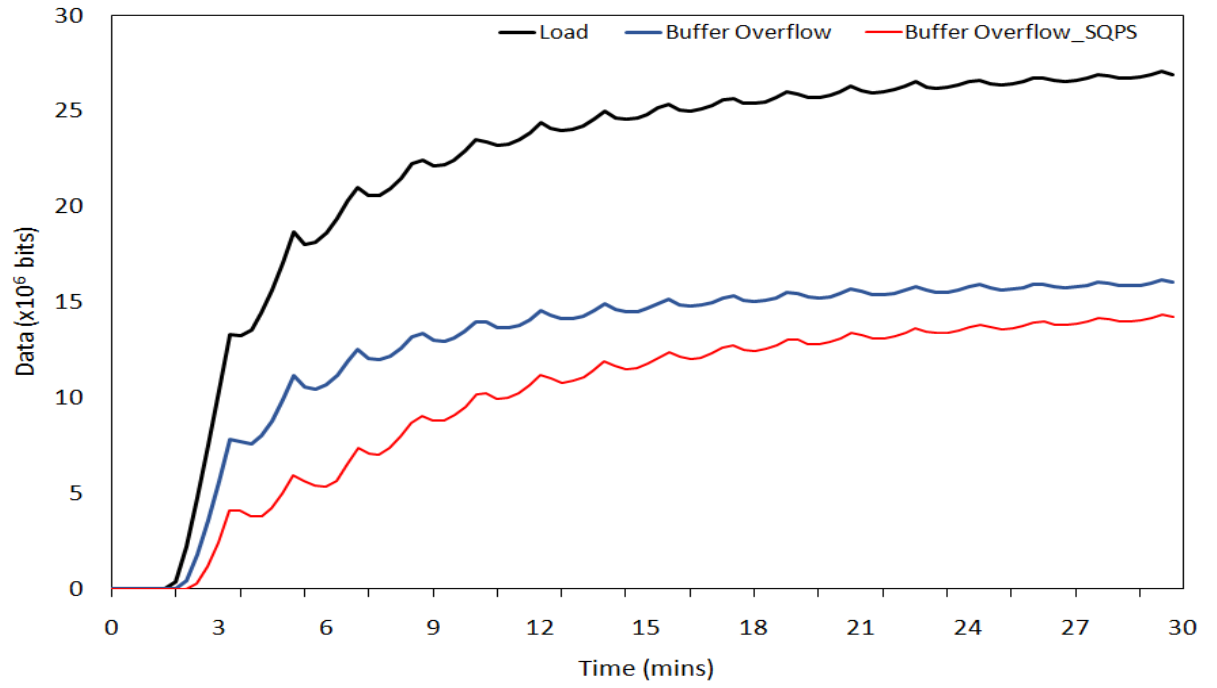
**Figure 4.10:** Average load and buffer overflow with and without SQPS (Eight-nodes).



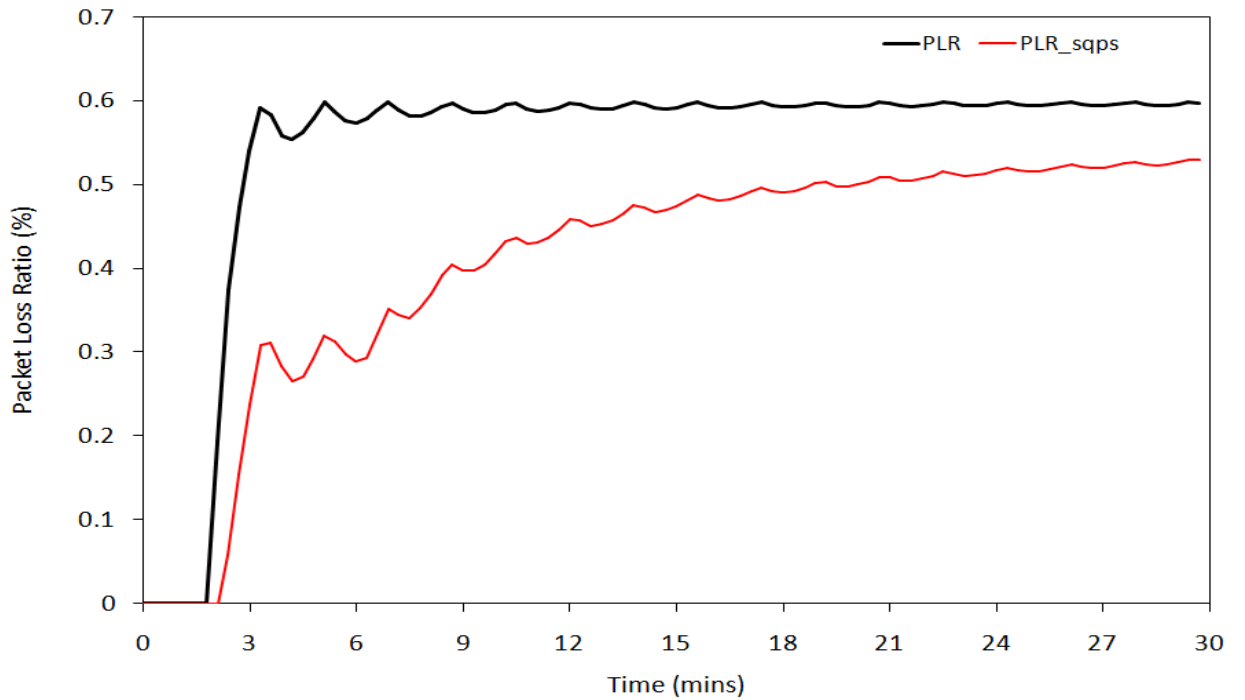
**Figure 4.11: Average PLR with and without SQPS (Eight-nodes).**



**Figure 4.12: Average efficiency of the SQPS (Eight-nodes).**

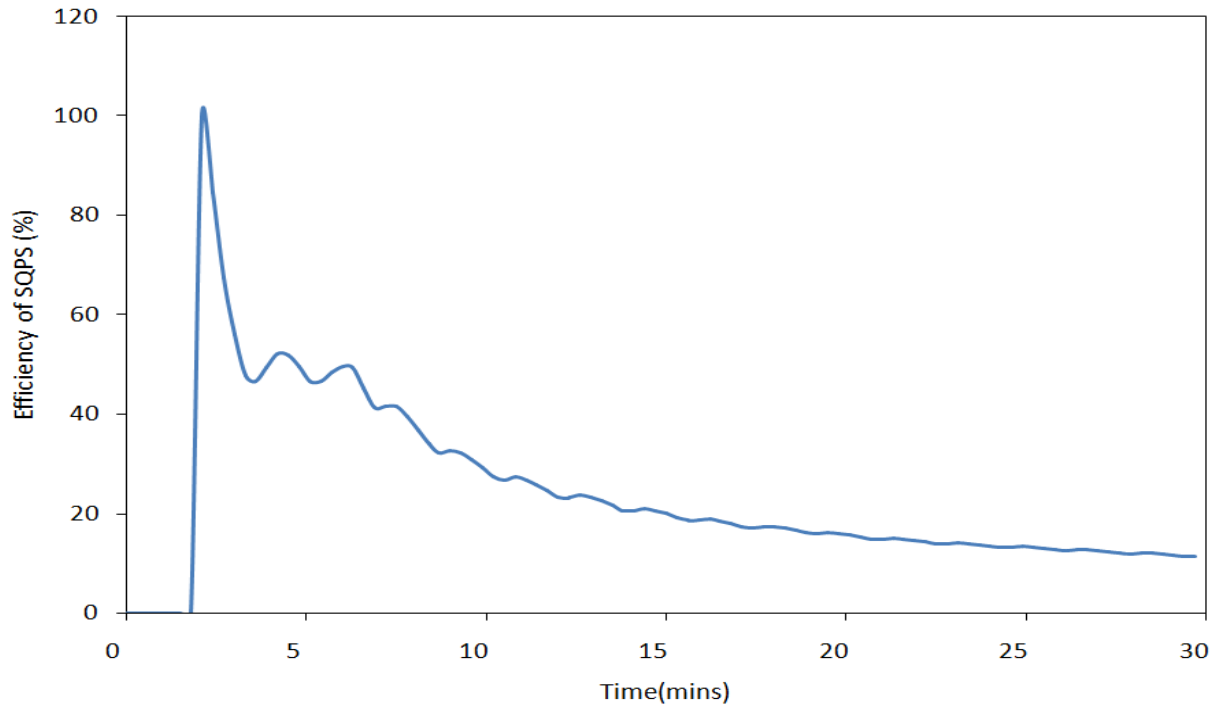


**Figure 4.13:** Average load and buffer overflow with and without SQPS (Ten-nodes).

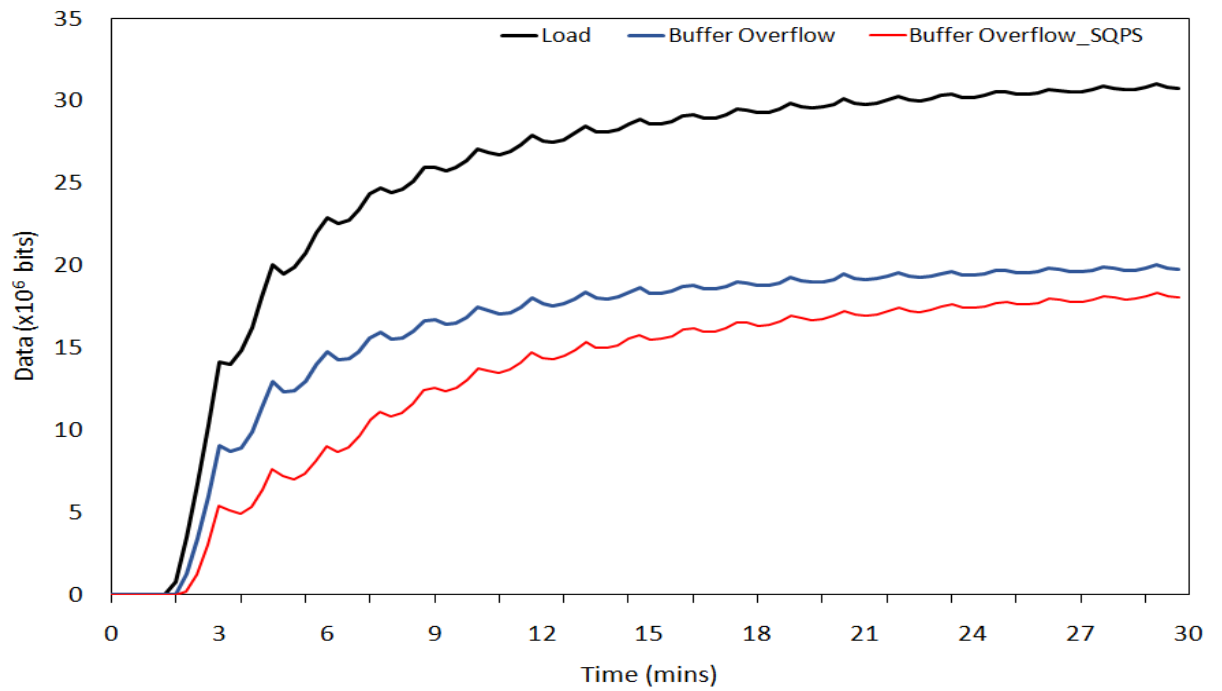


**Figure 4.14:** Average PLR with and without SQPS (Ten-nodes).

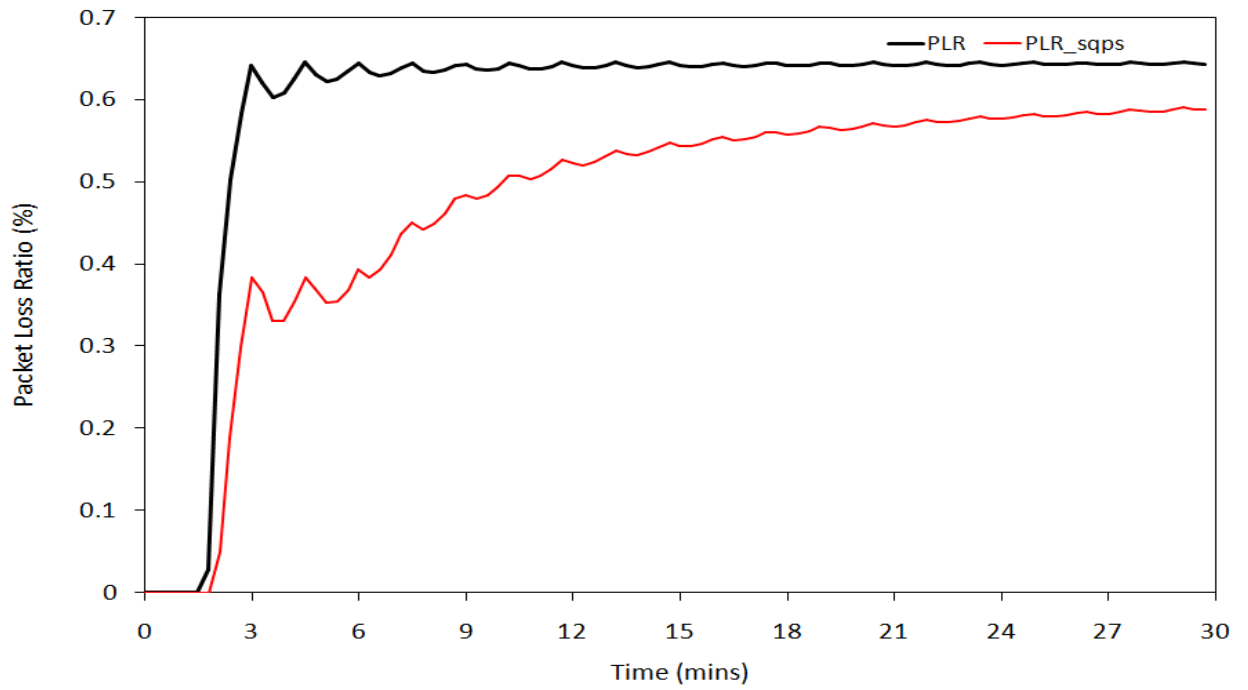




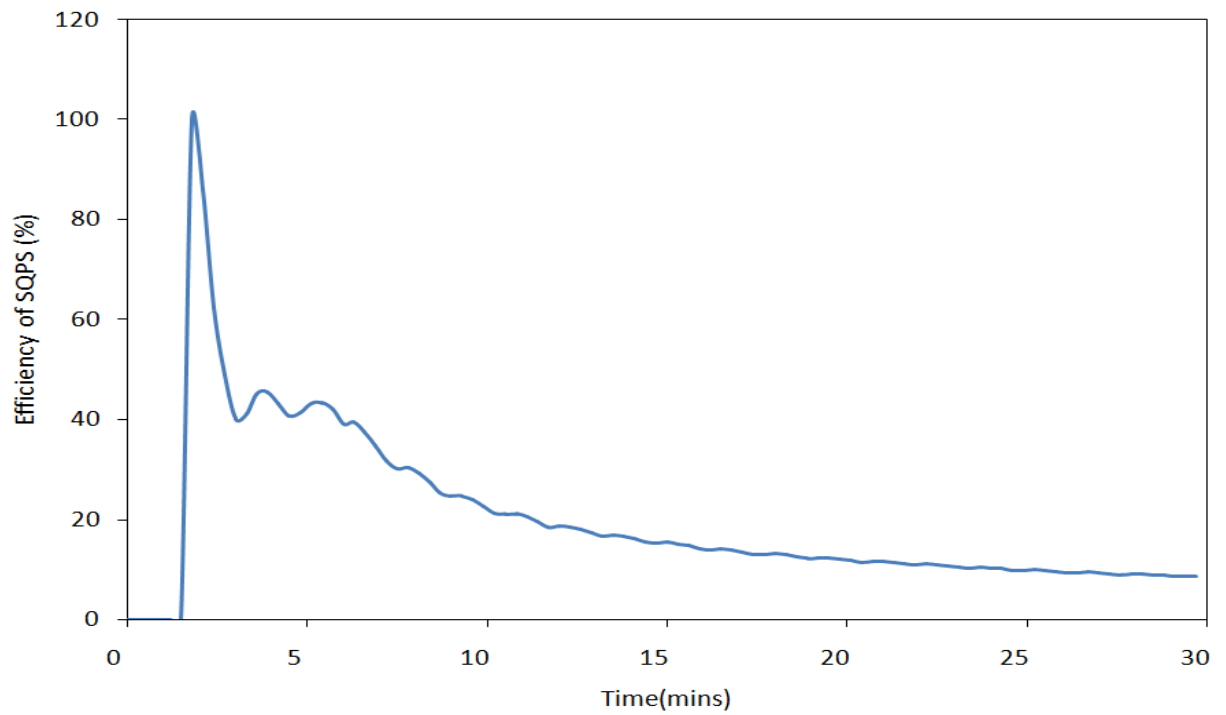
**Figure 4.15:** Average efficiency of the SQPS (Ten-nodes).



**Figure 4.16:** Average load and buffer overflow with and without SQPS (Twelve-nodes).



**Figure 4.17: Average PLR with and without SQPS (Twelve-nodes).**



**Figure 4.18: Average efficiency of the SQPS (Ten-nodes).**

## **5 Conclusion and Future Work**

### **5.1 Conclusion**

This study has tested the capability of Single-Queue Priority Scheduler (SQPS) in optimizing video transmission in WLAN. This work has contributed to address the challenges many mobile video transmissions face in standard wireless network (e.g. in Wireless Local Area Network (WLAN) or IEEE 802.11). As identified and discussed comprehensively in Chapter one, the challenges include handover, delay, packet loss, jitter, fading and signal loss. The study has shown that as there are huge demands and applications of video transmission, there are also expectation in terms of quality of service and to meet this expectation, there is a need for solutions to combat these challenges. The present study has shown that implementing SQPS in WLAN is a promising solution.

In Chapter two, the dissertation has reviewed past studies on various sources of the challenges, and on approaches of addressing the video transmission in WLAN. It showed that the sources of the problem in video transmission could be partly attributed to unbalanced traffic, resource constraints, variable network connectivity, and congestion in WLAN. It also showed that there are two major schools of thought in combating the challenges. The first school of thought proposes the network resources should be increased. The second school of thought proposes that instead of improving the resources, various aspect of the video transmission in WLAN can be optimized to obtained better transmission without compromising the quality of the transmission. The approach used in the study can be grouped under this second school of thought. This chapter also presented a literature review on different ways of optimising the WLAN; these include cross layer designs, multipath, priority, and error correction. The chapter also presented different approaches for evaluation of this solution and showed the efforts made by UCT's Electrical Engineering department in the optimisation of video streaming under the ARTIST project.

In the third chapter of this study, a detailed method of how the simulation is setup was presented. A workable scheduling algorithm-SQPS was developed and implemented. Three metrics were used in the design of the SQPS algorithm. They are deadline, priority and cost and assigned weights of 0.7, 0.2 and 0.1 respectively. The SQPS arranged and prioritized video frame using an SQPS value ( $S_n$ ) obtained from a linear combination of the three metrics. By assigning weights to the I, B and P video frames, the MPEG frame (trace file) was rearranged. These frames were then prioritized and arranged in a single queue. A parameter to actively arrange the queue ( $S_n$ ) was deduced from three metrics- deadline, priority and cost. This value  $S_n$  was used to arrange the video frames from the lowest to the highest. The arranged video frames were injected into the queue and transmitted in that order. I tested the SQPS using an infrastructure based WLAN with two wireless access points, a switch and nodes that varied from two to twelve in six scenarios. Our control simulation used a 6-node WLAN and sensitivity simulations with two, four, eight, ten and twelve nodes.

The fourth chapter captured the results of the simulation. Three graphs showing the buffer overflow, PLR and efficiency of the SQPS algorithm were obtained in all the scenarios. In our sensitivity to the number of nodes simulations, we observed that as the number of nodes increased, the traffic load and buffer overflow also increased. The simulation in the 2-node WLAN system showed that when the PLR reached 16.3%, the PLR with SQPS algorithm reduced to almost zero with a 99.9% efficiency. In the 4-node scenario, the PLR without SQPS amounted to 48.6% while PLR with SQPS did not exceed 19.4% achieving an efficiency of 81%. In the 12-node scenario, the PLR without SQPS amounted to 74% while PLR with SQPS did not exceed 54% achieving an efficiency of 45%. The efficiency of the SQPS decreased as the traffic load increased.

In line with the optimizing approach, the work proffered a solution to the video loss in IEEE 802.11 networks. It used the SQPS to rearrange the video frames based on their importance. The results show that the implementation of SQPS algorithm improves the video transmission in WLAN. Although, this scheduling algorithm produced better

results to reduce packet loss, there were still some losses in the network. However, efficiency of the SQPS algorithm in optimizing the WLAN decreases with transmission time and with the number of the WLAN nodes.

## **5.2 Future Work**

The weights assigned to the metrics (deadline, priority and cost) for the SQPS have been statically assigned. Further research can be done such that these weights are dynamically assigned with inputs from the current network performance. This will require some cross-layer algorithms and it will be a good research area to pursue. This can help to obtain better results.

Furthermore, it will be good to see these simulations performed with a test-bed and compare with the simulation results.

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